P3-158 ABATE, PJ*; RAMSAY, CN; Mitchell College; *peter.abate@my.mitchell.edu*
Morphometric analysis of the non-indigenous bryozoan Tricellaria inopinata
Life history traits in colonial animals, such as erect cheilostome Bryosoa, are extremely variable as many factors contribute to both the growth of the colony, and the growth of individual zooids within the colony. While photographic and tagging studies have been shown to be successful in measuring colonial growth, these methods are less reliable for flexible, joined, three-dimensional species. Counting individual zooids in a colony or measuring zooid length is very difficult and laborious, thus making ecological studies surrounding these organisms challenging. Through morphometric analyses, we sought to determine whether a correlation exists between a specific growth metric to use as a proxy for the total number of zooids. *Tricellaria inopinata* is a non-indigenous bryozoan which was recently introduced to the North-western Atlantic shores and has been an ecological and economic threat to nearshore waters. After identifying eight metrics to model the total number of zooids within *T. inopinata* colonies, preliminary results suggest the total number of branches and total length of major branches were significantly correlated with the total number of zooids. Using these findings, the total number of zooids of *T. inopinata* and other species of colonial bryozoans can more easily be assessed, which may facilitate further ecological experiments on these three-dimensional colonial organisms.

65-3 ABBOTT, E.M.*; DIAZ, K.; SAWICKI, G.; Georgia Institute of Tech.; *emily.abbott@me.gatech.edu*
The theoretical contributions of morphology to the power output of muscle-tendon units
During a jump, many animals enhance the power that is generated by their muscles as energy is transferred to accelerate their body's center of mass. We call this phenomenon power amplification. Historically, computational models demonstrated that tendons in-series with muscles enhance the rate of energy transfer. However, when we incorporated realistic muscle state properties (length-tension and force-velocity relationships) into similar models the amount of power transferred to a load was greatly limited. Yet, we know frogs, overcome limitations set by muscle through 1) morphological adaptations 2) pre-stretch of muscles and 3) catch systems that allow a muscle to store energy in tendons and aponeuroses. We explored these strategies with a Simulink Matlab model of a Hill-type muscle-tendon unit with inertial and gravitational loads. In this model, we swept a wide parametric space of tendon stiffnesses, effective mechanical advantages and pre-stretch conditions. We observed that at low mechanical advantages (EMA=0.12) there are more limited combinations of tendon stiffness and body mass where the power of the muscle transferred to the load is enhanced. However, if the effective mechanical advantage is larger (EMA = 0.3), there is a broader morphological space in which power amplification exists. In all conditions, pre-stretching the muscle-tendon unit increases the power transferred to the load because stretching "cheats" the system by adding initial energy and allowing muscle shortening onto, rather than away from the plateau of the length-tension curve. This computational approach allows us to understand the limits of the building blocks of power amplifying systems. Furthermore, this approach could help develop guidelines for actuating wearable devices capable of augmenting human performance during accelerative movements like jumping or sprinting.

P2-34 ABDULELAH, SA*; CRILE, KG; AWALI, S; KHALIL, HH; BELANGER, RM; University of Detroit Mercy; *abdullsa3@udmercy.edu*
An investigation of olfactory sensory neuron morphology in the crayfish (Faxonius virilis) following atrazine exposure
Atrazine is an herbicide that is heavily applied in agricultural areas in the Midwestern United States and can run-off and seep into surrounding aquatic habitats. Concentrations of atrazine can reach concentrations of >300 ppb. Previous research in our lab has shown that exposures to 80 ppb atrazine cause lasting deficiencies in the chemoreception of food and mate odors. Due to the fact that atrazine impairs chemosensory responses, the goal of this study was to determine the effect of atrazine on olfactory sensory neurons located in the lateral antennules of crayfish. In this experiment, we used three 15-day exposures (0, 80, and 300 ppb) to atrazine. Post treatment, lateral antennules were fixed, decalcified and cryoprotected. Medial segments were then sectioned on a cryostat. Antennule sections were stained with antibodies against tubulin, a protein found in neurons, and DAPI, a nuclear stain and imaged. Additionally, we used DiO to help determine the number of neurons present after treatment. Our preliminary data suggests that atrazine exposure causes degeneration of olfactory sensory neuron bundles or clusters, leading to impairments in chemosensory abilities.

P1-284 ABELS, JR*; RICHARDSON, SS; BIRD, NC; Univ. of Northern Iowa; *abelsjaa@uni.edu*
Histological Anatomy and Structural Integration in Four Distinct Cypriniform Weberian Apparatus Morphologies
The Weberian apparatus is a novel hearing adaptation found in otophysan fishes, a large group of freshwater fishes comprised of approximately 8000 species. Cypriniform fishes, the largest otophysan order, are abundant in the freshwaters of Asia, Europe, North America, and Africa. Such environmental variability has led to modification of skeletal structures in non-auditory portions of the apparatus (lesser so in the auditory elements), likely due to heavy constraint for the maintenance of functionality (Bird and Hernandez 2007). Within Cypriniformes, four distinct morphologies have been identified: Open (typical of Cyprinidae), Anterior Shield (typical of Gyrinocheilidae, Catostomidae, and Botiidae), Single-Capsule (typical of Cobitidae), and Double-Capsule (typical of Nemacheilidae and Balitoridae). Little information exists detailing the construction and integration of these morphologies at the tissue level. We used HBQ quad-stained paraffin histology and whole-mount clearing and staining to document and analyze the hard and soft tissue of the Weberian apparatus in species representing six genera (*Danio*, *Gyrinocheilus*, *Ambastia*, *Pangio*, *Schistura*, and *Sewellia*) that characterize all morphologies. We found minimal changes to the Weberian ossicles, swim bladder, and otic sensory structures across morphologies (typically relative changes in size, not shape). Several differences in the non-auditory structures were found among the species of the same morphotype, such as size and shape of lateral openings in the swim bladder capsule, and communication zones between right and left capsules. These results reveal unrecognized variability in the integration of the Weberian apparatus across different morphotypes.

P1-31 ABIRI, NF*; GALLOWAY, K; PORTER, ME; Florida Atlantic University; *nabiri2015@fau.edu*

Effect of orientation on the flexural stiffness of lionfish, Pterois volitans, dorsal spines using 3D printed models

The red lionfish, *Pterois volitans*, is native to the Indo-Pacific region, and has quickly proliferated along the Western Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. It has been shown to negatively affect the ecosystems it invades by decreasing biodiversity. Lionfish have 13 dorsal stings (the defense apparatus) which are comprised of a spine of mineralized collagen surrounded by a dermal sheath. The spines are tapered and have anterolateral grooves that create an anchor-like cross-section and store venom. We hypothesized that the cross sectional shape of the spines optimizes their ability to resist bending. For this study, we quantified lionfish spine flexural stiffness (EI), which takes into account both shape (I) and material (E), at varying locations of lateral point load. Due to the anchor-like cross-section, we predicted that EI of the spine will increase when the lateral point load is applied at the anteromedian ridge, where I will be the largest. We generated a digital 3D model of the 12th dorsal spine of a *P. volitans* and printed magnified (11.46x) resin models. We applied point loads at two locations on the spine models and compared them to models of I-beams. I-beams are frequently used in construction because of their high I, which increases EI relative to a solid beam. Similarly, lionfish spines have a large portion of their cross-section area located away from the neutral axis allowing for high I and EI with less material. Mechanical testing of lionfish spines is essential to understand the form and function of unique shapes found in nature.

P1-293 ABRAHAM, JO*; STAVER, AC; Yale University; *joel.abraham@yale.edu*

Drought-Response Strategies of Savanna Herbivores

Climate models have predicted increases in the frequency and severity of drought globally, with potential impacts on diverse systems, including African savannas. Among other things, droughts pose a concern for the conservation of the large mammal communities therein, and as such, understanding the behaviors that mammalian herbivores utilize to mitigate drought effects is vital. To evaluate herbivores responses to drought, we examined herbivore diet composition and landscape use in Kruger National Park, South Africa, during and after a severe but heterogeneous drought that occurred from 2014 to 2016. We found that mixed feeders responded to drought by increasing their consumption of C3 trees, shrubs, and forbs, while grazers and megaherbivores moved away from severely droughted areas towards drought refugia. Results suggest that, while herbivores can respond to drought behaviorally, their responses may be partially constrained by their body size and feeding ecology. Grazers may be at particular risk, since frequent and severe droughts may not always generate drought refugia, especially in smaller and/or fenced reserves. Conservation schemes should recognize these constraints and work to facilitate the diverse responses of herbivores to drought.

92-5 ACHE, JM; NAMIKI, S; LEE, A; BRANSON, K; CARD, GM*; HHMI Janelia Research Campus; *cardg@janelia.hhmi.org*

Descending Control of Landing in Drosophila

To survive, animals must respond to sensory cues in a context-specific manner. Even innate sensorimotor responses are flexible, such that an identical cue can elicit different actions in different situations. How the brain achieves this context-dependent flexibility, or 'makes decisions,' is unclear. In the fruit fly, *Drosophila melanogaster*, frontal looming stimuli elicit an escape takeoff if the fly is standing and a landing response if the fly is flying. While the neuronal basis of the escape response is relatively well-known, and relies, in part, on giant-axon descending neurons, little was known about the control of landing in any species. We created a collection of 130 transgenic lines that target individual, identified descending neurons. We conducted an optogenetic activation screen of this collection and identified two descending neuron bilateral pairs whose activation drives extension of all six legs with kinematics that resemble the landing response of the fly. Genetically silencing either of these descending neuron types significantly reduced landing responses elicited by frontal visual looming stimuli. Using whole-cell patch-clamp recordings, we show that landing descending neurons integrate visual and mechanosensory cues and control leg extensions in a graded fashion while the fly is flying. Critically, landing descending neuron visual responses are eliminated or severely attenuated when the fly is not flying. This gating occurs by separate mechanisms (neuromodulation or efference copy) in the two different landing neuron types. Our findings show that state-dependent gating of descending pathways is one mechanism that controls the brain's access to different motor networks, thus enabling flexible, context-dependent action selection.

P1-224 ADAMS, CIM*; JEUNEN, GJ; KNAPP, M; Univ. of Otago, New Zealand; *clare.adams@postgrad.otago.ac.nz*

Can haplotypes be recovered from environmental DNA?

Understanding population dynamics is imperative for conservation and management purposes. Recent development of the non-invasive environmental DNA (eDNA) technique allows for extracting organismal DNA from environmental samples such as water or soil. While successful in obtaining biodiversity data, few studies have proven the ability to obtain haplotype diversity. In this study, we aim to develop an eDNA approach for describing haplotypic variation in marine species of commercial and conservation interest, Pāua (*Haliotis iris*) and the New Zealand fur seal (NZFS) (*Arctocephalus forsteri*). We are developing a controlled laboratory experiment to obtain multiple haplotypes in varying ratios from water. Water will be spiked with differing ratios of Pāua and NZFS PCR products at a concentration of 100 copies/µL, and eDNA methodology will be used to extract the DNA. Once samples are sequenced, we will develop a bioinformatics pipeline to retrieve population genetic data of these target species. Relative sequence abundance will be compared to initial haplotypic ratios. The relationship between haplotype abundance and relative sequence abundance will be analyzed. Through developing a methodology for discerning haplotypes from water samples, we hope to widen the door for non-invasive genetic monitoring via eDNA.

115-4 ADAMS, DS*; ZHU, R; FISH, FE; West Chester Univeristy, University of Virginia, West Chester University; *da762671@wcupa.edu*

Properties and Functions of Tendons in the Peduncle of Odontocetes

Dorso-ventral oscillations of caudal flukes of cetaceans generate lift-based thrust that allows them to operate with a high propulsive efficiency. Flexibility of the tail flukes is an important element in this system and the ability to rotate the flukes about the ball vertebra allows for changes in angle of attack and smooth bending. There are three sets of tendons that pass through the odontocete peduncle and insert onto the caudal vertebrae. It is unknown to what extent these tendons affect fluke flexibility. The purpose of this study was to investigate direct effects of peduncle tendons on odontocete fluke flexibility, deflection angle and investigate tendon elasticity. One-point bending tests were conducted on isolated harbor porpoise (*Phocoena phocoena*) flukes that were immobilized at their base. Tension was created by the addition of weight to each tendon. Tensile testing was performed on harbor porpoise and striped dolphin (*Stenella coeruleoalba*) tendons using an Instron 5848 MicroTester. Histological analyses of collagen fibers were performed on the tendons. Flexibility of the fluke decreased and deflection angle increased as a result of tension applied to tendons indicating the possibility that these tendons play a role in controlling fluke stiffness and thrust production. The stiffness differed among tendons in the peduncle and was overall more compliant than average mammalian tendons. The collagen fibers that make up the three sets of tendons in the cetacean peduncle were found to be longitudinally wavy, suggesting the ability to store elastic energy. In addition, the terminal ends of two tendons branched into the core of the flukes. These results indicated that there is potentially active control of flexibility in odontocete flukes during locomotion.

S2-10 ADELMAN, JS; Iowa State University; *adelmanj@iastate.edu*

Linking immunological mechanisms and transmission consequences of tolerance in a songbird host

Tolerance of infection, or minimizing the fitness losses for a given pathogen load, should have dramatic impacts on the dynamics of wildlife diseases. However, empirical studies of the mechanisms underlying tolerance and its consequences for pathogen transmission remain limited. Among animals, tolerance manifests in two principle ways, behavioral vs. tissue-specific tolerance, with the potential to either enhance or impede transmission. Behavioral tolerance maintains fitness-enhancing behaviors during infection, likely leading to increased contact rates and enhanced spread of directly transmitted pathogens. On the other hand, tissue-specific tolerance reduces damage to tissues (pathology), which could hinder transmission of certain pathogens by limiting dissemination routes (e.g. diarrhea, coughing). This presentation outlines recent and ongoing research into the mechanistic causes and transmission consequences of tolerance in an ecologically relevant wildlife disease system: house finches infected with *Mycoplasma gallisepticum*. This bacterial pathogen jumped into finches from poultry in the mid-1990s, causing pronounced conjunctivitis and reduced survival in the new host. Using the severity of conjunctivitis as a proxy for fitness during experimental infections, we have found that lower pro-inflammatory immune signaling predicts enhanced tissue-specific tolerance. These results are consistent with reduced inflammatory responses as proximate drivers of tolerance in this system. In addition, recent experimental epidemics in captivity suggest that tissue-specific tolerance may have a larger impact on transmission than behavioral tolerance, although prior work has highlighted a key role for behavior in the transmission of this pathogen. I discuss the implications of these findings on host-pathogen interactions at the ecological and evolutionary time scales.

114-2 ADEOLA, FI*; LAILVAUX, SP; University of New Orleans; *slailvaux@gmail.com*

Octopamine mediates mating interactions and sexual conflict in the house cricket (Achaeta domesticus)

Mating interactions are rife with conflict because the evolutionary interests of males and females seldom coincide. Intersexual conflict modifies the opportunity, form, and intensity of sexual selection, yet the proximate factors affecting male coercive ability and female resistance are poorly understood. The invertebrate neurotransmitter octopamine both mediates aggression and underlies motivation to bite in male house crickets, but we currently lack an understanding of the influence of bite force and octopamine levels on mating interactions in these animals. We manipulated octopamine through supplementation with excess octopamine and administration of an octopamine antagonist, epinastine, to test the influence of octopamine on mating success in *Acheta Domesticus* crickets. We show using formal selection analysis that bite capacity influences the outcomes of mating interactions in house crickets, and that those outcomes are further altered in crickets with manipulated octopamine levels relative to unmanipulated controls.

P2-15 ADHIKARI, H*; SIA, T; DAVIDSON, B; Swarthmore College; *hadhika1@swarthmore.edu*

Actin dynamics facilitate localized trafficking of growth factor receptors

Actin dynamics play vital role in regulating the trafficking of receptor proteins, which ultimately impacts the way cells signal. We study signal processing in embryos of the invertebrate chordate, *Ciona robusta*. In *Ciona*, asymmetrically dividing heart founder cells undergo differential induction to produce heart progenitor and tail muscle lineages. Previous research has shown that Arp2/3 activity, which nucleates branched actin, is required to localize induction in the *Ciona* founder cells. We are investigating the role of branched actin dynamics on the localization of fibroblast growth factor (FGF) receptors, upstream of induction. ARP2/3 inhibitor studies indicate that actin dynamics are required to suppress degradation and regulate polarized trafficking of fluorescently tagged FGFR. We are currently examining whether myosin motors contribute to these actin-dependent steps in FGFR trafficking. Our findings suggest that mutations impacting actin dynamics may drive changes in membrane trafficking and cell signaling associated with oncogenesis.

P2-211 ADJERID, K*; SOOD, N; DE VITA, R; SOCHA, JJ; Virginia Tech, Pulaski High School; *adjerid@vt.edu*

Variation of Young's modulus and taenidial density in the tracheae of a darkling beetle

Some insects facilitate active ventilation by rhythmically compressing their tracheal tubes. When collapsed, the tubes take on an uneven pock-mark like appearance, with patterns that vary across tracheae, individuals, and species. We hypothesize that deformation patterns result from variation in material or structural properties of the tubes. The semi-chitinous walls of the tracheae are reinforced with rings of stiffer sclerotized chitin fiber bundles called taenidia, which vary in branching, width, and orientation. To investigate tracheal properties, we first measured Young's modulus along the lengths of excised sections of tracheae using atomic force microscopy (AFM). We then measured variation in packing density of the taenidia using SEM images of the same tracheal sections. Preliminary results show that the Young's modulus varied substantially along the length of the excised sections of tracheae (1.67 ± 2.67 GPa; n=7). Moduli were distributed bimodally, with relatively little variation about the low mean (0.66 ± 0.30 GPa) and greater variation about the high mean (7.40 ± 1.27 GPa). The inter-taenidial spacing varied between 1 to 5 µm. In some specimens, the average spacing increased gradually (~0.11 µm per 100 µm of trachea), whereas in others, it changed rapidly (by up to ~1.33 µm per 100 µm). It is possible that regions with low taenidial density or low Young's modulus may serve as initiation sites for tracheal compression, but this hypothesis remains to be tested. Supported by NSF 1558052 and 1301037.

97-5 AGAN, JA*; LOVERN, MB; GRINDSTAFF, JL; FOX, SF; Oklahoma State University; *justin.agan@okstate.edu*

How Collared Lizard, Crotaphytus collaris, Hatchling Orange Bars Affect Male-Male Interactions

Collared lizards, *Crotaphytus collaris*, are sexually dimorphic lizards in which males use their sexually selected traits to defend territories against rivals and to attract females. While not novel, collared lizards are different from other animals in that they present a sexually dimorphic trait as hatchlings that is replaced by adult dimorphic traits once the lizards reach sexual maturity. Hatchlings male lizards develop orange dorsolateral bars that are lost as the lizards become sexually mature. Juvenile males are aggressive toward other juvenile males and use these orange bars in this context. We tested how these orange bars are affecting male-male interactions by conducting behavioral trials that separated the effect of the bars from aggressive behavior. Lizards either had their bars removed (masked with paint) or enhanced (increased area with spectrally similar paint) and received either a hormone implant that increased dihydrotestosterone levels and aggressive behavior, or a blank implant. Treatment lizards were placed in a neutral arena with an unaltered and size-matched stimulus male and behaviors of both lizards were scored to measure relative aggression. Trials showed that the bars and aggressive behavior are linked and that increasing one, either the bars or the aggression, will oppositely alter the outcome of male-male interactions. While lizards with increased aggression via hormone implants were significantly more aggressive in comparison to blank implanted lizards and non-implanted stimulus lizards, lizards with only enhanced orange bars were met with an increase in aggression. When the orange bars were enhanced without the associated level of aggression expected, rival males retaliated against the "cheater" male. This means that lizards police those that act outside of the bounds of their signal.

66-6 AICHELMAN, HE*; BOVE, CB; CASTILLO, KD; BOULTON, JM; KNOWLTON, AC; RIES, JB; DAVIES, SW; Boston Univ., Univ. of NC, Chapel Hill, Northeastern Univ.; *haich@bu.edu*

Reef Zone-Specific Physiological Responses of Two Caribbean Corals Exposed to Multiple Global Change Stressors

Global change is threatening coral reefs, with rising temperature leading to repeat bleaching events (dysbiosis of the coral host and its symbiotic algae Symbiodiniaceae) and increasing $p\mathrm{CO}_2$ causing reductions in calcification. Global bleaching events are revealing fine-scale patterns of coral survival; however, the physiological phenotypes that lead to success under stress remain elusive. Here, we conducted a 90-day experiment to investigate the physiological responses of two Caribbean reef-building coral species (*Siderastrea siderea* and *Pseudodiploria strigosa*) from nearshore and forereef locations on the Belize Mesoamerican Barrier Reef System under ocean warming (28, 31°C) and acidification (280-2800 µatm $p\mathrm{CO}_2$). Calcification, total host protein and carbohydrate, chlorophyll a pigments, and symbiont cell density were quantified in order to characterize the acclimatory responses of each coral host and their symbionts to these global change stressors. Overall, forereef *P. strigosa* were more negatively affected by temperature, but not $p\mathrm{CO}_2$, in all aspects of physiology measured when compared to nearshore counterparts. This effect was observed at even the first timepoint, suggesting this forereef *P. strigosa* population will be negatively affected by long term heat events. In contrast, *S. siderea* did not appear to be negatively affected by heat, $p\mathrm{CO}_2$, or the interaction of the two stressors over the course of this experiment for any of the physiological responses considered. Our future work will incorporate transcriptomic comparisons of the same individuals to examine underlying molecular mechanisms driving these species and reef zone differences.

104-3 AIELLO, BR*; HAMILTON, CA; KAWAHARA, AY; SPONBERG, S; Georgia Institute of Technology, Florida Museum of Natural History; *brett.aiello@physics.gatech.edu*

Big wings and agile flight: evolutionary patterns of moth morphology and stability in Bombycoidea

Moth wing and body morphology, which evolve to meet the functional demands of a species, will influence both aerodynamic capacity and agility. In the morphologically diverse moth superfamily Bombycoidea, the sister-groups Sphingidae (hawkmoths) and Saturniidae (silkmoths) are known for their highly maneuverable and erratic flight patterns, respectively. Aerodynamic theory suggests that both low wing aspect ratio (AR) and wing loading enhance maneuverability, while high AR wings enhance aerodynamic efficiency. Interspecific variation in morphology is also expected to influence the inherent stability and maneuverability of an animal. To test these hypotheses, we quantify forewing morphology and loading across Bombycoidea. Maximum likelihood ancestral state reconstruction of wing AR and loading reveal patterns of divergence and convergence across the tree. With few exceptions, hawkmoths exhibit wings of higher AR and loading relative to silkmoths. Based on each group's respective ability to maneuver, these patterns of hawkmoth and silkmoth wing AR and loading contradict the expectation. The evolution of high AR wings in the hawkmoth clade might be related to the group's ability to hover. Further, several more recent smaller transitions in wing shape and loading indicate pairs of species facing significantly different neuromechanical challenges. These results are integrated into a wider analysis of bombycoid flight stability as a function of wing morphology, body inertia, and physiology in order to explore the correlated evolution of neural and mechanical determinants of flight performance in these diverse agile organisms.

P2-250 AKESSON, KC*; WARD, AB; MEHTA, RS; Univ. of California, Santa Cruz, Adelphi Univ. ; *kakesson@ucsc.edu*
Investigating Axial Diversity and Movement in Elongate Amphibious Fishes

The ability of fully aquatic animals to overcome the water to land transition raises a fundamental question - how is movement facilitated on land? Body elongation has evolved repeatedly within aquatic vertebrates with some of the earliest tetrapods having more elongate forms. The repeated evolution of fishes with elongate bodies poses pivotal questions about how body shape affects life strategies and habitats and how body shape may enable fishes to cope with a dynamic environment. Here, we investigated the underlying axial diversity in fishes with eel-like body plans that are known to make terrestrial excursions to varying degrees. In addition to an elongate body, these fishes tend to have reduced or lost their pectoral fins, which results in movements that tend to be propelled exclusively by the body. We measured a set of external characteristics as well as traits that comprise the axial and appendicular skeleton for 30 species of fishes representing diverse ecological and evolutionary histories. For a subset of these fishes, we conducted locomotor trials on a wet pebble substrate to characterize variability in movement patterns to better understand the relationship between morphology and motion. Our preliminary data suggests that external characteristics varied more across elongate species than we previously anticipated but that dorsoventral flattening of the body versus a taller more laterally compressed body resulted in similar locomotor patterns. It has been previously posed that irrespective of how elongate a fish is, lateral undulation in the terrestrial environment may be characterized by anterior to posterior waves. Our preliminary work shows that this is the case even when examining species that have comparable lengths but different means of elongating the body and subtle differences in secondary axis reduction.

P2-193 AKINKUOTU, RT*; MENDONCA, MT; Auburn University; *rta0009@auburn.edu*
Interaction of violacein produced by various Chromobacterium ribotypes and chytrid fungus at different temperatures

Chytrid fungus, *Batrachochytrium dendrobatidis* (Bd) has been one of the major source of amphibian decline worldwide. This fungus grows and colonizes the keratin layer of the amphibian skin. Different kinds of bacteria inhabit the skin of amphibians, where some of these bacteria can cause inhibition of the activities of Bd. A violacein-producing bacteria (*Janthinobacterium lividum*) is one of the most studied anti-Bd bacteria but there are Chromobacterium spp that equally produce (a) similar metabolite(s) and have received less study. We identified 4 ribotypes of *Chromobacterium* (*C. sphagnii, C. substugae, C.vaccinii, C. amazonense*) isolated from skin swabs of cricket frogs collected from wetlands in the Tuskegee National Forest during several sample periods throughout the year. We tested the violacein-type metabolite produced by each of these 4 ribotypes against three of the most pathogenic strains of Bd at a series of 4 different temperatures (12°C, 16°C, 20°C, 24°C). We hypothesized that the violacein-type metabolites produced by the different ribotypes of *Chromobacterium* will vary in their ability to inhibit Bd and this variation will be temperature dependent. The bioassay was done using cell-free supernatants from three-day old tryptone broth cultures of each ribotype. When the Bd cultures had reached maximal growth, we challenged each with the supernatants of each of the ribotypes. *C. sphagnii* exhibited the most inhibitory effect, reducing growth by 60% during the bioassay for three of the Bd strains at 20°C We also observed slow growth of Bd as well as its inhibition at 12°C for all 4 ribotypes. This study shows that these set of violacein-type producing bacteria are also abundant and important in mitigation of Bd infection of amphibians.

22-6 ALAASAM, VJ*; DUNCAN, R; CASAGRANDE, S; DAVIES, S; SIDHER, A; SEYMOURE, B; SHEN, Y; ZHANG, Y; OUYANG, JQ; University of Nevada, Reno, Max Planck Institute for Ornithology, Quinnipiac University, Colorado State University; *valentina@nevada.unr.edu*
Not So Cool: Cool Color-Temperature Light Disrupts Nocturnal Rest and Elevates Glucocorticoids in Zebra Finches (Taeniopygia guttata)

Nighttime light pollution is quickly becoming a pervasive, global concern. Since the invention and proliferation of light-emitting diodes (LED), it has become common for consumers to select from a range of color temperatures of light with varying spectra. Yet, the biological impacts of these different spectra on organisms remain unclear. We tested if nighttime illumination of LEDs, at two commercially available color temperatures (3000K and 5000K) and at ecologically relevant illumination levels affected body condition, food intake, locomotor activity and glucocorticoid levels in zebra finches (*Taeniopygia guttata*). We found that individuals exposed to 5000K light had higher rates of nighttime activity (peaking after one week of treatment) compared to 3000K light and controls (no nighttime light). Birds in the 5000K treatment group also had increased corticosterone levels from pre-treatment levels compared to 3000K and control groups but no changes in body condition or food intake. Individuals that were active during the night did not consequently decrease daytime activity. This study adds to the growing evidence that the spectrum of artificial light at night is important, and we advocate the use of nighttime lighting with warmer color temperatures of 3000K instead of 5000K to decrease energetic costs for avian taxa.

43-7 ALBERY, GF*; KENYON, F; BECKER, DJ; NUSSEY, DH; PEMBERTON, JM; University of Edinburgh Institute of Evolutionary Biology, Moredun Research Institute, Scotland, Montana State University, Bozeman, MT; *g.f.albery@ed.ac.uk*
The Landscape of Immunity in a Wild Ungulate Population

Parasite infection in the wild is extremely spatially heterogeneous. This is well-understood at large scales, yet little is known about the way that immunity and parasitism vary at small scales and within populations. Here we used a wild population of individually recognised Scottish red deer (*Cervus elaphus*) to investigate how immunity and parasitism were associated with their spatial and social behaviour. We collected 2,000 noninvasive faecal samples from 450 known individuals over the course of three years, using a thorough censusing operation to examine their behaviour. We quantified mucosal antibody levels and helminth egg shedding and analysed them with GLMMs using INLA, with spatially distributed random effects to quantify spatial autocorrelation. We discovered strong spatial trends across the study population, with profoundly different antibody levels and parasite intensities in individuals living in different areas. Spatial heterogeneity was present despite the fine sampling scale and considerable mixing, and distributions differed substantially for different parasites and antibodies. Our results confirm that immunity and parasitism can vary sharply across space, and suggest that the density of conspecifics and exposure to secondary hosts are important in determining distributions of both immunity and parasites in this system. We conclude that small-scale spatial variation may be affecting the disease ecology of wild animal populations, and this should be taken into account in more studies where possible.

S7-12 ALFARO, ME*; KARAN, EA; CHANG, J; WOO, LK; ALFARO, Michael; UCLA; *michaelalfaro@ucla.edu*

High Throughput Phenoscaping for Comparative Studies

As major sections of the Tree of Life become increasingly resolved, a central challenge for comparative study involves the scaling of phenotypic data collection efforts. Here we explore two techniques that enable high throughput (thousands to tens of thousands of species) data collection and analysis of 2D images. The first uses crowd-sourcing through the Amazon mechanical turk interface and involves a web browser-based landmarking application that is deployed to remote workers. These workers may be paid (through the Amazon mechanical turk framework) or the browsing application can be distributed to citizen scientists or research teams to facilitate parallelization of data collection. We demonstrate how this approach can be flexibly adopted to collect geometric morphometric and spatial distribution data. The second uses supervised and unsupervised machine learning to classify fish color patterns. We illustrate how image data may be used to train classifiers to recognize fish color pattern traits at broad phylogenetic scales and explore unsupervised algorithms for color pattern discovery.

113-1 ALI, RS*; WELCH, KC; Univ. of Toronto; *raafay.ali@mail.utoronto.ca*

Plasma membrane (PM) recruitment patterns of glucose transporters (GLUT) 1, 2, 3, and 5 in response to feeding in the ruby-throated hummingbird, Archilochus colubris.

Hummingbirds rely entirely on recently ingested carbohydrates to fuel rested and exercising metabolism as well as the *de novo* synthesis of lipids. Their flight muscle cells have the capacity for rapid phosphorylation of both imported glucose and fructose. Facilitative glucose transporters (GLUTs) regulate the flux of glucose and fructose across biological plasma membranes (PMs) and into active cells. We examined ruby-throated hummingbird (*Archilochus colubris*) flight muscle and liver for changes in GLUT protein abundance and localization in response to feeding. We observed GLUT-5 protein in the flight muscle PM, supporting previous findings that suggest a unique fructose-processing capacity of hummingbird flight muscle. We also show the lack of GLUT-1 protein in hepatocytes, despite previously observed GLUT-1 transcript. Finally, we found that feeding increases the PM abundance of glucose-specific GLUT-isoforms (GLUT-1) in the flight muscle, while the liver PM increases in both glucose- and fructose-specific GLUT-proteins (GLUT-2, GLUT-3). This suggests that, while hummingbird muscle show capacity for fructose import and phosphorylation, only glucose-specific GLUT-isoforms are dynamically regulated in response to feeding. In the liver, both glucose- and fructose-specific GLUT-isoforms are dynamically regulated suggesting that the liver may predominately transport ingested fructose. This study provides further insights into how hummingbirds manage the partitioning of recently ingested glucose and fructose to optimize their daily energy needs.

P3-74 ALJEBOURE, SS*; MCALISTER, JS; College of the Holy Cross; *ssalje19@g.holycross.edu*

Investigating Maternal Effects in the Sea Anemone, Nematostella vectensis, from Chronic Exposure to 17β-Estradiol.

An organism's phenotype is the product of its genotype, the environment that the organism experiences as well as the environment experienced by its mother. The effects of the maternal environment on phenotype expression in offspring are termed maternal effects and they can have critical impacts on offspring development, growth, and performance. Maternal exposure to stress and toxins can result in physiological, behavioral, and developmental changes in offspring. In most marine invertebrates, the effects of acute or chronic exposure to these agents are unknown. We aimed to determine whether chronic maternal exposure to the endocrine-disrupting chemical, 17β-estradiol, has effects on the growth, behavior, feeding, and potentially the development of adults and offspring of a common saltmarsh invertebrate, *Nematostella vectensis*. In our study, anemones were exposed for 35 days to one of 7 treatments: seawater control, DMSO control, and 0.1, 1, 10, 100, 1000 ng/mL of 17β -estradiol. Anemones were spawned prior to, and at 1, 3, and 5 weeks during the exposure period; unfertilized eggs were collected from females and frozen for later biochemical constituent analyses, which are ongoing. During the exposure period, anemones in the highest doses of 17β-estradiol displayed deflated morphologies and tentacle retraction, behaviors that were dissimilar to anemones exposed to low concentrations of 17β-estradiol or the two control treatments. These behaviors may have impacted maternal provisioning of eggs with biochemical constituents, particularly lipids, as 17β-estradiol is a lipophilic molecule. The results from this study provide information on how chronic exposure to marine toxins can potentially lead to altered behavioral and developmental outcomes in mothers and their offspring.

P2-221 ALLEN, JW*; DAVIS, JS; High Point University; *jallen1@highpoint.edu*

Comparative Morphology of Jaw Adductors in Chiropteran and Carnivoran Dietary Specialists

Mastication is a complex process that involves the use of three dimensional jaw movements to direct precise occlusion between teeth to break down food. Several studies have noted that in mammalian species with a fused mandibular symphysis, late activity of the balancing-side zygomaticomandibularis produces transverse masticatory jaw movement. This is thought to produce lateral transverse bending or "wishboning" forces at the mandibular symphysis, which can be resisted by ossification of this joint. The current study investigates the hypothesis that mammals that have specialized on plant-based diets and have a fused mandibular symphysis will also have a larger, more complex zygomaticomandibularis than their closest animalivorous relatives. In this study, contrast-enhanced microCT scans of representative dietary specialists from orders Chiroptera (bats) and Carnivora (carnivorans) are used to compare size and orientation of the primary jaw adductors, with particular emphasis on the compartments of the masseter (including zygomaticomandibularis). We find that within the carnivoran sample, our hypothesis is supported, but within the chiropteran sample, this signal is somewhat more complicated: while the zygomaticomandibularis does form a larger proportion of the masseter in frugivorous species, the masseter itself is much larger in the animalivorous species. We discuss possible functional explanations for our observations.

72-4 ALLEN, PE*; MILLER, CW; University of Florida; *pabloallen@ufl.edu*

Environmental and Genetic Factors Contribute to the Divergence in Weaponry Across a Broad Landscape

Animal weapons include such intriguing structures as horns on bighorn sheep, antlers on deer, and tusks on elephants. In spite of the interest these structures have attracted, we still do not know why there is such amazing weapon diversity. Through this project we aimed to understand how weapon differences arise even within a species, to provide insight on early divergence of weapon shape and size. Patchy but widely distributed species, such as the leaf-footed bug *Narnia femorata* (Hemiptera: Coreidae), are good candidates to study the processes that can lead to the diversification of animal weapons. This cactus-feeding species is found in the US Southwest and Florida, and has known association with at least four genera and 13 species of cacti through its extensive range. Adults are sexually dimorphic, females have on average larger bodies but males have enlarged hind femurs used in male-male combat. Males establish territories on their host plants and defend them against other conspecifics using their hind legs [=weapons]. Larger males are more likely to be dominant over smaller ones when defending their territories. Combining fieldwork with common garden/reciprocal transplant experiments, we examined the variation of male weapon morphology across a broad landscape. We found both phenotypic plasticity and evolved differences in weapon shape and size. Interestingly, the divergence in weaponry is mainly due to changes in allometric intercepts of hind femur traits (length and width) and body size, with no changes in allometric slopes. We discuss possible implications for population divergence in the context of the combat behavior of this species.

P3-33 ALLRED, LA*; KANE, EA; OUFIERO, CE; Georgia Southern Uni., Towson Uni.; *la01413@georgiasouthern.edu*

Comparison of Swimming Energetics Between Damaged and Healthy Bluegill Sunfish (Lepomis macrochirus)

Locomotion is key to survival of many fishes and depends upon their ability to use their body and fins to generate thrust. Economic swimmers should exhibit lower metabolic rates at a given swim velocity, allowing energy to be used for other tasks. However, previous studies disagree on whether fin damage impairs swimming energetics. A common metric to assess swimming performance and energetics is critical swimming speed (U_{crit}) which forces fish to swim continually at increasing incremental speeds. However, the energy used at higher speeds may be confounded by the duration of the trial. The purpose of this study is to find out if fin damage impacts swimming energetics and whether differences are repeatable using modifications to the U_{crit} protocol. Bluegill sunfish (*Lepomis macrochirus*) are common in the United States and have been used in previous studies on swimming performance. Bluegill were collected from a hatchery using a monofilament cast net, which caused fin damage (n=6 damaged fish), and an electrofisher, which did not damage fins (n=6 healthy fish). Fish were randomly exposed to 6 ecologically relevant flow speeds (5-30 cm/s) in a swim tunnel respirometer for 10 minute intervals with 5 minutes of rest between speeds. All fish were tested again at least 2 weeks later using different randomization of speed intervals. We predict that damaged fish will repeatedly display higher metabolic rates at each speed compared to healthy fish. Allowing rest periods between randomized changes in speed should reduce exhaustion as a limiting factor and increase repeatability of measurements. This study has the potential to shed light on the consequences of fin damage for locomotor performance in bluegill.

P2-118 ALVAREZ, Y*; ADAMS, NL; California Polytechnic State University, San Luis Obispo; *yaalvare@calpoly.edu*

Mother knows best: Maternal investment causes differences in UV-tolerance of intertidal and subtidal populations of sea urchins

Planktonic larvae of many marine organisms are increasingly being exposed and required to respond to a changing physical environment. As *Strongylocentrotus purpuratus* adults occupy intertidal and subtidal waters, many questions remain about how populations residing at different depths adequately prepare their offspring to cope with different levels of UVR. In this study, *S. purpuratus* adults were collected from two intertidal and two subtidal (15 m) sites from the central coast of CA to compare UV tolerance in offspring. UVA (321-400 nm) and UVB (280-320 nm) measurements at the four collection sites were at minimal or absent levels in subtidal sites. Our study found that offspring from intertidal populations have a less severe developmental delay when exposed to environmentally relevant levels of UVR using artificial lighting than offspring from subtidal populations. The mean percent cleavage delay for UV-treated embryos relative to the controls was 17.6% for intertidal sites and 23.4% for subtidal sites. Although these embryos are members of the same species and share a common genetic background, they differ in their phenotype and chances of survival due to differences in maternal resources. This suggests that environmental UV cues or additional environmental cues experienced by intertidal mothers may reduce the negative effects of UV exposure during early development. To further explore the role of maternal investment, we are using a proteomic approach to assess differences in protein expression between eggs from intertidal and subtidal populations. This will offer insight into how protein variation provides embryos with a rapid response to stress during early development.

P1-141 AMBROSE, A*; ORTIZ, C; CORDERO, C; CHMABERS, C; MARKLAND, S; OSBORN, A; SHIRLEY, K; TWOMBLY ELLIS, J; TSCHEULIN, T; GIRAY, T; BARTHELL, J; AGOSTO-RIVERA, J; Savannah State University , University of Puerto Rico Rio Piedras, University of Kansas, Oklahoma State University, College of New Jersey, Colorado College , Cornell University , University of the Aegean , University of Central Oklahoma; *alexandria.ambrose13@gmail.com*

The role of circadian rhythms on the temporal organization of foraging behavior in three carpenter bee (Xylocopa) species in a Mediterranean Island Ecosystem

Bee pollinators are an indispensable aspect of the environment, by providing pollination services to the plant communities that shape our ecosystems. As the environment undergoes changes, including climate change, having a better understanding of the endogenous circadian rhythms in pollinator species could allow us to sustain pollination of plant species in both agricultural and natural systems. Like other animal species, pollinator species have their own circadian rhythm in which they have a peak or trough of foraging activities throughout the day. These peaks or troughs can be influenced by environmental cues. We hypothesized that if circadian rhythms play a major role in the timing of foraging behavior in *Xylocopa* species, then their activity patterns in the lab (in the absence of environmental timing cues) would resemble their patterns in the field. To test the hypothesis, we compared *Xylocopa violacea*, *Xylocopa olivieri*, and *Xylocopa iris* forging patterns in the field to their activity in the lab under constant environmental condition. We found that *X. olivieri* and *X. iris* activities in the lab closely resembled their foraging patterns in the field. *X. violacea* activity in the lab was longer in duration than in the field. All three species were more active during the middle of the day in the lab than they were in the field. The resemblance between foraging behavior in the field and the intrinsic activity pattern in the lab under constant conditions indicates that circadian rhythm plays a major role in the timing of foraging behavior among these species.

P2-92 AMBROSE, A.; CHAMBERS, C.; CORDERO MARTINEZ, C.; MARKLAND, S.; OSBORN, A.; SHIRLEY, K.; TWOMBLY ELLIS, J.; SILVA ECHEANDIA, S.; GIRAY, T.; GONZALEZ, V.; HRANITZ, J.; BARTHELL, J.*; Savannah State University, University of Kansas, University of Puerto Rico, Rio Píedras, Oklahoma State University, The College of New Jersey, Colorado College, Cornell University, University of Puerto Rico, Rio Píedras, Bloomsburg University, University of Central Oklahoma; *jbarthell@uco.edu*

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

We observed three species of carpenter bees foraging at the chasteberry bush, *Vitex agnus-castus*, on the Northeast Aegean island of Lesvos (Greece). Observations were made at 30-minute intervals during a 14-hour period (sunrise to sunset). Simultaneously (but reported elsewhere) we observed activity patterns of the same bee species in the laboratory for endogenous, circadian rhythms. We found distinct patterns among the species that appeared to correspond with the size of each species. The largest bodied species, *Xylocopa violacea*, was most commonly seen during the earlier and later periods of the day while the smaller bodied *X. iris* was dominant during the middle of the day. The third species, *X. oliveri*, was restricted to very early or very late periods of the day, including during dim light. We predict that a mixture of ecological and genetic factors causes differences in foraging times. Larger bodied species have a physiological advantage during cooler periods of the day (given their reduced ability to radiate heat) while smaller bodied species can forage during the hottest time of day when larger species are rare or absent. Subsequent results of the thermotolerance of these species are consistent with this conclusion. Our results also suggest, however, that *X. oliveri* has greater endogenous constraints on its range of foraging times than the other two species. For these reasons, we believe these species represent an ideal study system for understanding the foraging dynamics of pollinators within flowering plant communities.

P2-147 AMODEI, NF*; TOBALSKE, BW; POWERS, DR; George Fox University, University of Montana; *namodei16@georgefox.edu*

Use of Post-Hovering Behavior to Dissipate Accumulated Heat in Hummingbirds

Hummingbirds generate a large amount of heat during flight due to the low mechanical efficiency of their flight muscles and they must dissipate that heat to avoid overheating. Heat can be dissipated passively (convection, conduction, and radiation) and by evaporation (respiratory and cutaneous). When environmental temperatures are high, passive heat dissipation is eliminated leaving evaporation as the only option for thermoregulation. In hummingbirds, respiratory evaporation accounts for < 40% of metabolic heat production, requiring the balance of metabolic heat production to be dissipated by cutaneous evaporation. Aerodynamically positioned feathers restrict passive heat dissipation during flight, but it is unknown if cutaneous evaporation will be affected as well. We studied evaporative heat dissipation at temperatures near the limits for passive heat dissipation in hovering calliope (*Selasphorus calliope*), Rivoli's (*Eugenes fulgens*), and black-chinned (*Archilocus alexandri*) hummingbirds using open-flow respirometry and video recordings. Cutaneous evaporation was estimated as total evaporation minus respiratory evaporation. Our measurements in calliope hummingbirds suggest that they are unable to sufficiently upregulate cutaneous evaporative water loss to compensate for the extra heat produced during hovering. Observations of all species studied suggest that post-hovering behaviors might be important for rapidly dumping heat following a hovering bout in warm conditions.

P3-175 AMONETT, SD*; BALENGER, SL; University of Mississippi; *sdamonet@go.olemiss.edu*

Maternal Effects in Response to Mycoplasma gallisepticum Infection in Eastern Bluebirds

Neonates lack adaptive immunity and are vulnerable to pathogens. Mothers can transfer passive immunity to offspring by transmitting antibodies (Abs) via milk or yolk. Mothers previously or currently infected with a pathogen transfer Abs to newborns, granting them immunological protection until they can synthesize their own. In birds, Abs are deposited before eggshell formation within the mother's oviduct. Similarly, mothers may transmit pathogens that colonize the oviduct. It was recently found that wild eastern bluebirds (*Sialia sialis*) are common hosts of the avian pathogen *Mycoplasma gallisepticum* (MG). We sampled 40 nestlings laid by MG-positive mothers and found 15% of nestlings were positive for MG Abs. The MG bacterium is known to be vertically transmitted in poultry. It colonizes the oviducts of infected hens and is transmitted to embryos during egg formation. My study will monitor a population of eastern bluebirds to test: the adaptive nature of specific MG antibodies, if infected female bluebirds harbor MG bacteria in their oviduct and transmit MG to their eggs, and the differences in both antibody and disease transmission between first and second broods. I will quantify MG Ab concentrations in eggs, nestlings, and adults. I will use PCR to identify active MG infections in female birds. If egg transmission of MG is occurring, then maternal Abs would provide critical immunological support to embryos exposed during development. This study will provide insight into non-genetic, maternal effects on offspring survival and growth in response to a costly infection.

P3-55 AMPLO, H.E.*; CRAWFORD, C.H.,; FLAMMANG, B.E.; Rutgers University-Newark, New Jersey Institute of Technology; *hea7@njit.edu*

Head, Shoulders, Elbows, Fins: Frogfish Fin Morphology

Frogfishes (Family Antennariidae) are highly derived teleost fishes that utilize multiple modes of locomotion, including ambulating on their pectoral fins, in order to move through diverse habitats. Previous literature describes the pectoral fin as having both a shoulder-like and an elbow-like portion, the functions of which are key to frogfishes ability to "walk" with their pectoral fins.These pectoral fins contain small scapula and coracoid bones united by cartilage and three fin radials, the third being distally expanded, articulating with a cartilaginous bar that attaches to a variable number of pectoral fin rays. Frogfishes are also unique in that they have developed 14 muscles associated with the pectoral girdle instead of the 3 muscles typical among neoteleosts, which may aid in their ability to rotate their fins severely around these joints. However, the internal morphology of these unique locomotor adaptations are not well described, or illustrated. In this study, the pectoral fin and pectoral girdle of the shaggy frogfish, *Antennarius hispidus*, are described using microCT scanning, PTA staining, and clear and stain techniques in order to describe the unique shoulder-like and elbow-like morphologies within the frogfish fin. Future work will include kinematic and electromyographic analyses to explore how this novel pectoral fin structure allows Antennariid fishes to employ their pectoral fins for walking-like locomotion, and explore the evolutionary life history of this unique group of fishes.

P2-210 AMTHOR, A*; LUNA, M; YAEGER, J; NOEL, A; NADLER, J; Georgia Tech Research Institute; *aria.amthor@gatech.edu*

Characterization, Imaging, and Evaluation of High-speed Fluid Transport Inspired by a Hummingbird's Tongue

Hummingbirds embody the extreme: their lifestyle of speed and maneuverability necessitates a high rate of caloric intake achieved through an average licking frequency of 13.8 Hz (Ewald and Williams 1982). However, the conventional assumption of capillary action in their tube-like tongues cannot transport fluid fast enough to account for such behavior. Instead, recent research has revealed that their tongues are not composed of two simple tubes, but that each has a comma-shaped cross section that curls in response to surface tension like a planar torsion spring. This geometry leads to the ability to passively unfurl and reseal around trapped fluid, as well as pump fluid up the unsubmerged tongue 5 times faster than allowable through capillary action (Rico-Guevara 2015). In this experimental study, we observe and image the kinematics of an ex-vivo *Archilochus colubris* tongue dipping into water and characterize the material properties of the tongue tissue. We found the elastic modulus to be orders of magnitude higher than that of tongue tissues in other species used as comparison. This lends a usable stiffness to the spring mechanism which allows it to restore its shape after compression and create a negative pressure to drive fluid up the tube. Simultaneously, it remains pliable enough to be curled by surface tension. We explore potential materials to capture this range of stiffness as well as fabrication methods taken from soft lithography to form soft 3D materials. This structure can inspire new ways to trap and pull fluid passively, for applications such as fluid containment and diffusion in diapers.

P3-103 AN, D*; HUSOVIC, A; ALI, L; WEDDLE-PITTMAN, E; NAGLE, L; AHEARN, GA; Univ. of North Florida; *gahearn@unf.edu*

Ocean acidification: Synergistic inhibitory effects of protons and heavy metals on ^{45}Ca uptake by lobster branchiostegite membrane vesicles

This paper describes ion transport mechanisms present in the plasma membranes of lobster (*Homarus americanus*) branchiostegite epithelial cells and the effects of pH and heavy metals on the uptake of ^{45}Ca by these processes. Partially purified membrane vesicles (PPMV) of branchiostegite cells were produced by a homogenization/centrifugation method. ^{45}Ca (1 mM) uptake was highest at pH 8.5 and decreased in a step-wise fashion at pH 8.0, 7.5, and 7.0 with lowest uptake occurring at pH between 6.0 and 7.0. ^{45}Ca uptake was a biphasic process consisting of a saturable mechanism at low [Ca] and a linear process at higher [Ca]. ^{45}Ca influxes (15 sec uptakes) at both pH 8.5 and 7.5, in the presence of 100 µM verapamil (Ca channel blocker), were both hyperbolic functions of [Ca], with the Michaelis-Menten constant (Km) significantly greater at pH 7.5, suggesting competitive inhibition between protons and ^{45}Ca during uptake. Increasing zinc concentrations (5 to 500 µM) reduced apparent carrier-mediated 1 mM ^{45}Ca uptake at pH 8.5 and 7.5 completely, the remaining uptake being accounted for by channel uptake and non-specific isotope binding. Uptake of 1 mM ^{45}Ca at pH 8.5, 7.5, 7.5 + Zn, and 7.5 + Zn + Cu in the presence of 100 µM verapamil displayed a step-wise reduction of ^{45}Ca uptake with addition of each treatment until only non-specific isotope binding occurred with all cation inhibitors. Results suggest that branchiostegite uptake of ^{45}Ca takes place by carrier-mediated and channel proteins. Carrier-mediated ^{45}Ca uptake is synergistically abolished by the combination of increased acidity and heavy metals.

P1-279 ANABLE, N*; GIBB, A; MINICOZZI, M; Northern Arizona University; *nra62@nau.edu*

Kinematics of Burying Behavior in the Pacific Staghorn Sculpin

Many marine fishes from divergent teleost lineages hide in the substrate to avoid predators or to ambush prey, but the mechanisms by which fishes insert their bodies into the substrate are still poorly understood. We examined the kinematics of burial in the Pacific staghorn sculpin (*Leptocottus armatus*) and asked: how does the deep-bodied sculpin bury its body into the substrate? We filmed *L. armatus* individuals (n=7) voluntarily burying using two high speed cameras (recording images from synchronized dorsal and lateral views) and tracked points on the fish over time using a MatLab routine (DLT data viewer, created by Ty Hendrick). Displacement data for each tracked point (head, tail and body) were subsequently smoothed with a quintic smoothing spline to derive velocity and acceleration. The Pacific staghorn sculpin buries by raising its head and tail simultaneously, then forcefully bringing both ends of the body downward, onto the substrate. During the down-stroke, the sculpin appears to simultaneously force water out of the ventral margin of the opercles (gill cover) to inject water into the sand. Pacific staghorn sculpins also use their pectoral fins to push sand laterally out from underneath the body and they alternate fin movements over time. Dorso-ventral body movements and pectoral fin movements are repeated cyclically at approximately 0.75-second intervals until the fish is approximately 60% buried. It appears that Pacific staghorn sculpins use a combination of undulations, injection of water into the substrate from the cranium, and physical removal of substrate by the pectoral fins during burial behaviors. These data provide ecologically significant insights into the behavior of this species, but also may provide new mechanisms to bury human infrastructure and equipment (bridges or ship anchors) into sandy substrates.

S3-8 ANDERSON, P. S. L. *; CROFTS, S. B.; Univ. of Illinois, Urbana-Champaign; *andersps@illinois.edu*

Making an impact: Energy transmission during high-speed puncture events

An organism's ability to control the timing and direction of energy flow within its body is vital to maintaining proper function. But what happens when the organism transfers this energy to a target outside its body? Take, for example, a snake injecting venom into prey, a sting ray stinging in self-defense or a trap-jaw ant attacking an invader with its spring-powered jaws. In all three cases, the organisms are attempting to puncture their targets through the transfer of energy from their bodies into the target. However, this is not a straightforward procedure. Energy transferred between systems can be lost via deformation of the tool or target, imparting momentum to the target, and creating heat. The success or failure of a puncture attempt is dictated by how well the puncturing and target organisms control the energy flow between them. While the puncturing organism can influence how energy is delivered to the target, the material properties of the target dictate the target's reaction. My lab has begun to examine the influences of kinematic and structural factors on energy transfer during dynamic puncture events by performing high-speed experiments using both synthetic and biological tools and targets. Preliminary results show scale-dependent trends in energy transfer between puncture tool and target. For example, while increased speed allows for increased fracture in targets, there is an upper limit to this, which is partly controlled by the relative masses of the tool and target. Experimental analyses such as this will open the door for establishing a common framework for examining energy transfer dynamics between organismal systems across scale and phylogeny.

P3-82 ANDERSON, T*; GLASS, J; JOHNSON, D; STAHLSCHMIDT, Z; USDA-ARS, Univ. Pacific; *tavis.anderson@ars.usda.gov*

Predicting variation in life-history traits using multilayer environmental and physiological networks

Shifts in complex environments characterized by multiple co-varying factors present organisms unique challenges. The dynamic interplay among life-history traits, underlying physiological mechanisms, and the environment remains a fundamental, though poorly understood, issue. We quantified the effects of temperature (field-parameterized heat wave vs. control diel cycles), diet (low vs. high food availability), and immune activation (LPS challenge vs. no challenge) on parameters of life history (investment into growth, reproduction, and flight musculature) in the sand field cricket (*Gryllus firmus*), which exhibits a wing dimorphism that mediates a flight-fecundity tradeoff. We further quantified physiological parameters of total protein concentration and phenoloxidase activity, and metabolic rate. To predict how physiology and environments interactively influence life history, we used a hierarchy-aware unsupervised feature learning approach. We built a multilayer network where each layer represented interactions among individual life-history traits and physiology within different conditions (e.g., one layer was derived from individuals that experienced a heat wave, low food availability, and immune challenge): network nodes were linked across layers resulting in a multilayer network. An unsupervised machine learning algorithm was trained to automatically predict life-history trait values using features derived from the network. We also measured degree centrality, clustering coefficients, centrality scores, and diffusion to determine the relative importance of each parameter in the network to life history. We show that accounting for dynamic environmental variation and underlying physiology improves the power to predict variation in life-history traits linked to fitness.

75-7 ANDERSON, RA*; MCBRAYER, LD; Western Washington University, Georgia Southern University; *Roger.Anderson@wwu.edu*

Long term patterns of habitat use and prey use in a dietary specialist

Many important questions in science are based on fundamental queries. A fundamental question in ecology includes understanding the spatial and temporal patterns displayed by organisms, and defining the processes that generate those patterns. With respect to terrestrial vertebrates, understanding the effects of habitat variation and food availability requires a multi-year perspective, given the multi-year lifespans of vertebrates. Desert scrub locales are especially conducive to investigating how annual climate variation and prey availability affect the predator's diet, habitat selection, and home range size. A useful study system for such work is the ant-eating specialist Desert Horned Lizard, *Phrynosoma platyrhinos*. We studied a population in three contrasting mesohabitats—dunes, flats and hardpan—in the Alvord Basin of southeastern Oregon, which is near the northern extent of the lizard species' geographic range. For 18 years, habitat use of male and female lizards was investigated in early summer. Home range size and habitat use were quantified via radio-tracking and powder-tracking for 13 of 18 years. Annual variation in spatial patterns of prey diversity among habitats varying in shrub types and sizes were also measured and correlated to lizard locations and movements. The relationships elucidated will provide the basis for more integrative analyses of habitat use beyond prey availability, such as mate search, dispersal, antipredation and thermal constraints.

29-8 ANDERSON, SJ*; COWLES, DL; Walla Walla University; *Sarah.Anderson@wallawalla.edu*

Is the Eelgrass Isopod a Vector for Labyrinthula zosterae Wasting Disease on Zostera marina?

Zostera marina eelgrass, an important foundation species for many temperate coastal marine ecosystems in the North Pacific and North Atlantic, is nevertheless vulnerable to pathogens. In particular, the protist *Labyrinthula zosterae*, which causes eelgrass wasting disease, has at times swept through eelgrass populations with devastating effects. Although *L. zosterae* has not recently caused widespread epidemics, it continues to be present at low but varying levels in eelgrass beds, including those in Washington State. Knowing the factors which can affect its spread is important for management of eelgrass. The eelgrass isopod *Pentidotea resecata* is a common inhabitant of eelgrass in Washington State, with high abundance in Padilla Bay. *P. resecata* lives and feeds on eelgrass and, as an accomplished swimmer, travels from blade to blade. In this laboratory study we tested whether *P. resecata* serves as a vector for spreading wasting disease by its travel among and feeding on the eelgrass blades. During 12-day laboratory experiments, eelgrass blades exposed only to seawater developed virtually no wasting. Blades placed near infected blades developed substantially more wasting lesions. Allowing the isopods to travel back and forth between the blades further increased the prevalence of wasting, while the greatest incidence was produced by direct contact of infected blades with the clean blades. These results indicate that, in conjunction with other important variables, *P. resecata* can serve as a vector for the spread of eelgrass wasting disease.

13-8 ANDRADE LOPEZ, JM*; PANI, AM; MINOR, PJ; LOWE, CJ; Stanford University, UNC; *andradej@stanford.edu*

Nervous system evolution: A molecular genetic characterization of neural cell types in S. kowalevskii

Hemichordates are a key deuterostome phylum for understanding the evolution of the chordate CNS. Their nervous system is organized around two elements; a pervasive nerve plexus concentrated anteriorly, and two nerve cords; one dorsal and one ventral. Despite the major organizational differences between the nervous system of hemichordates and vertebrates, they share a well-conserved gene regulatory network for anterior-posterior patterning. It is still unclear whether any of this conserved pattern regulates any fundamental similarities in neural cell type specification. I will present data on the spatiotemporal expression of neural markers, including genes involved in neurotransmitter synthesis and transport by in situ hybridization, to determine the level of regional specialization of the neural plexus and nerve cords in juvenile S. kowalevskii. These data also facilitate more direct neural comparisons with chordates. I will also present data using a meganuclease, transposon - mediated approach, to generate transgenic animals expressing GPF in a small subset of neurons. These experiments facilitate an analysis of the identity and location of specific neural cell bodies, and also neuronal morphology and connectivity to better understand the structure and function of this nervous system. We have generated constructs to label neurons using pan-neural (synapsin, elaV, Syt1) and cell type specific markers (GAT, Nurr1, TH), and an endogenous synaptic vesicle protein, synaptotagmin, to label synapses. I will present a preliminary analysis of these data and their impact on our understanding of the comparative relevance of hemichordate nervous systems to broader questions of nervous system evolution. This work will give insights into the evolution of deuterostomes and the origins of the vertebrate brain, but also the evolution of bilaterian nervous systems.

P2-65 ANDRES, A*; SEIBEL, BA; SLESINGER, E; SABA, G; SABA , V; MORRIS, J; University of South Florida, Rutgers University, Rutgers University, NOAA, Mote Marine Laboratory; *alyssaandres@mail.usf.edu*

How Low Can Predators Go? Hypoxia Tolerance of Coastal Shark Species of Varying Lifestyle

Environmental oxygen availability, relative to requirements, is an important determinant of habitat suitability for marine organisms and provides a measure of effective metabolic scope for all life functions beyond basic maintenance. As the balance between metabolic oxygen demand and environmental supply changes with climate, energetic trade-offs occur to facilitate survival, or alternative habitat is sought to alleviate metabolic constraints. As the global incidence of low oxygen waters, known as hypoxic zones, increases each year, it has become crucial to understand how marine organisms respond to hypoxia. Coastal shark species of varying lifestyle such as blacktip sharks (*Carcharhinus limbatus*), and spiny dogfish sharks (*Squalus acanthias*)) may be vulnerable to hypoxia due to oxygen-intensive behaviors, such as high-speed swimming, migration, etc. Hypoxia, in conjunction with temperature-induced increases in oxygen demand, may limit performance and viable habitat of coastal shark species. In order to accurately forecast shark niches, and habitat selection in the face of these climate shifts, we must first determine species-specific tolerances to hypoxia. Hypoxia tolerance was measured using Pcrit, defined as the critical oxygen partial pressure at which oxygen demand equals supply. Using respirometry, we determined Pcrit for *C. limbatus* and *S. acanthias*, and examined how Pcrit varies with ventilation method and temperature. Furthermore, we quantified behavioral responses to hypoxia and the blood stress response associated with acute exposure to critical oxygen levels. Results from this study provide a physiological basis for predicting viable metabolic habitat for these species, and insight into the physiological consequences of hypoxia-induced stress.

62-2 ANGELINI, DR*; MOORE, JA; SIMMONS, WR; AVERILL, AL; Colby College, University of Massachusetts, Amherst; *david.r.angelini@gmail.com*

Neonicotinoid exposure alters microbial composition and host gene expression in the gut of the bumblebee, Bombus impatiens

Bumblebees are common and charismatic pollinators that play a critical role in the ecology of northern temperate and boreal ecosystems. However, in recent decades anthropogenic environmental changes, such as increased use of pesticides, the spread of bee-specific diseases and habitat destruction, have led to declining numbers for wild bee species around the world. Neonicotinoid pesticides have been a focus of efforts to understand pollinator declines. The systemic nature of neonicotinoids or their derivatives mean they persist in the nectar and pollen of plants after application where they have been found to reduce individuals' foraging efficiency, colony fitness, and increase susceptibility to disease. Importantly, the mechanisms by which neonicotinoids affect bumblebee immunity are not well understood. We have used high-throughput DNA and RNA sequencing to examine the affects of agriculturally relevant concentrations of imidacloprid, the most commonly used neonicotinoid, on the composition of gut microbiota and host gene expression in the common eastern bumblebee, *Bombus impatiens*. We find significant gene expression changes at all doses, notably associated with immune and neural functions. High doses of imidacloprid also significantly reduced the relative abundance of Acetobacteraceae, including *Saccharibacter* sp., which are known to promote pathogen resistance in honeybees. These results suggest that neonicotinoids such as imidacloprid may lead to disease susceptibility in bees in part via altered microbial-host interactions and resulting dysbiosis.

S10-2 ANGILLETTA, MJ*; LEVY, O; SEARS, MW; VANDENBROOKS, JM; Arizona State Univ., Tel Aviv Univ., Clemson University, Midwestern University; *ma@asu.edu*

The Fundamental Flaws of Fundamental Niche Models

Biologists have increasingly used mechanistic models to predict species ranges during global change. Still, these models require assumptions about fundamental niches that severely limit their current value. First, models assume that animals avoid abiotic stress through microhabitat selection but fail to consider the costs of doing so. Second, models ignore covariances and interactions between abiotic variables such as temperature, humidity, pH, and pO2. Given these assumptions, researchers will fail to anticipate novel stresses faced by organisms in future environments. To address this problem, we present models in which organisms must balance the benefits of microhabitat selection with the energetic cost, predation risk, and missed opportunities. These models account for interactions among abiotic dimensions of the fundamental niche, which ultimately constrain fitness in real environments. In some cases, these models predict qualitatively different responses to global change than simpler models.

P2-40 ANSELMO, CM*; BUTLER, JM; MARUSKA, KP; Louisiana State University; *cansel5@lsu.edu*

The Lateral Line System Mediates Reproductive Interactions in the African Cichlid Fish, Astatotilapia burtoni

The mechanosensory lateral line system of fishes is essential for sensing nearby water movements, and functions in schooling, orienting in currents, locating prey, and detecting and evading predators. However, less is known about its role in social interactions. Previous work in our lab demonstrated that the cichlid *Astatotilapia burtoni* uses mechanosensory information detected by the lateral line system to mediate male-male territorial interactions. Many fishes also produce water movements during courtship and reproductive interactions, but we know little about the role of the lateral line system in reproduction in any of the ~30,000 species of fishes. To examine the role of mechanoreception in reproduction, we compared behavioral interactions and neural activation patterns associated with courtship in lateral line-intact and -ablated females. We quantified reproductive behaviors of both sexes: female response to male courtship, average proximity of the fish pair, and spawning rates. Preliminary data suggests that the lateral line affects reproductive behavior in both sexes, such that males perform fewer courtship behaviors towards ablated females than towards intact females, and ablated females have an altered response to male courtship attempts. To investigate neural processing of reproductively-relevant lateral line information, brains were collected after behavior trials and stained for the immediate early gene *cfos* as a proxy for neural activation. We are comparing neural activation patterns in sensory and socially-relevant brain regions in lateral line-intact and ablated groups. This study is the first to integrate behavioral and neural activation analyses to show the importance of the lateral line system in mediating reproductive communication in any fish species.

105-4 ANTONIAK, GJ*; BISWAS, T; CORTES, N; SIKDAR, S; BHANDAWAT, V; Duke University, Loyola University, George Mason University, George Mason University; *gja8@duke.edu*

Generalized Model of Locomotion

The movement of the body during legged locomotion can be modeled using simple mechanical models such as the spring-loaded inverted pendulum (SLIP). SLIP contains a leg that compresses and relaxes during the stance phase tracking the motion of the center of mass (COM) during running. One limitation of SLIP is that it can only model radial forces along the leg, and thus cannot overcome destabilizing gravitational forces. To overcome this limitation, we propose the angular and radial spring-loaded inverted pendulum (ARSLIP). ARSLIP extends SLIP with a torsional spring at the leg-foot joint whose rest position is the vertical orientation of the leg. The resultant tangential forces oppose gravity during the stance phase. The goal of the study is to assess how well SLIP and ARSLIP model the forces and COM kinematics during the single support phase of walking across a range of speeds. During this phase, the horizontal velocity and the vertical height do not change excessively, and the vertical ground reaction force (GRF) is a significant fraction of body weight. We used dimensionless analysis to find the gaitspace, the parameter region that falls within the biologically observed range in height, velocity, and GRF variation. SLIP could model slow walking only for a limited parameter range and only for short steps. ARSLIP can model both slower and faster steps across the parameter space. To further test how well the two models capture the walking gait, both SLIP and ARSLIP were fit to human GRF and COM data during the single support phase. While SLIP can model the M-shaped vertical GRF of human walking, SLIP struggles with the horizontal GRF, overestimating its amplitude. ARSLIP alleviates this issue by bringing the horizontal GRF in line with experimental data.

S8-8 ARBOUR, Jessica H*; CURTIS, Abigail A; SANTANA, Sharlene E; University of Washington, UW/Burke Museum; *jarbour@uw.edu*

Macroevolutionary Dynamics of Cranial and Mandible Shape in Bats

Bats represent the one of the largest (1300+ species) and most ecologically diverse orders of mammals, and exhibit a remarkable range of sensory and feeding specializations. Here, we explore the impacts of conflicting functional demands from both sensory and dietary functions on the evolution of skull shape within the bat radiation. We generated 3D geometric morphometric datasets of the skull of more than 200 species representing all bat families, dietary niches and types of echolocators. We used these data in a series of phylogenetic comparative analyses to uncover the macroevolutionary patterns and processes shaping skull diversity across bats. These included: (1) comparisons of an estimated adaptive landscape (with no a priori assumptions) of cranial and mandible shape evolution with transitions in diet and echolocation type across bats, (2) quantification of patterns of skull shape disparity across the evolutionary history of bats, and (3) tests of associations between shifts in skull modularity skull and ecological transitions. We found numerous adaptive shifts in skull shape evolution among bats; early shifts were associated with transitions between echolocators and non-echolocators, as well as between oral and nasal emitters, while later shifts in skull shape evolution were associated with diet within Phyllostomidae. Model fitting further supported a divergence between the major ecological pressures on cranium and mandible shape. Early shifts in echolocation seem to have strongly modulated cranial disparity and may have been associated with changes in skull modularity and lability. Conversely, shifts in skull shape may have been driven by dietary opportunities within Phyllostomidae. Together, these results demonstrate how the varying importance of different functional demands may impact the evolution of skull shape.

128-3 ARIAS, AA*; AZIZI, E; University of California, Irvine; *adriena@uci.edu*

Limb joint mechanics during incline and decline locomotion in Alligator mississippiensis

Legged locomotion across non-level terrain poses several challenges to animals, requiring them to adjust their limb joint kinematics and kinetics to either dissipate or produce more mechanical energy. These strategies used can shed valuable insight into which muscles are crucial during a limb's given function (e.g. braking or propulsion). Previous work has investigated the effects of slope (i.e. incline or decline) on the limb mechanics of various taxa, but such movements in non-erect quadrupeds remains poorly understood. Here we compare the limb joint mechanics of the American alligator, a semi-erect quadruped, during locomotion across a sloped (15°) and level trackway. We use high-speed videography (dorsal and lateral views) and force plate ergometry on juvenile alligators walking down a 15° decline, up a 15° incline, and across a level trackway. We show that mechanical function remains segregated between limb pairs as forelimbs (FLs) tend to provide more a braking function, whereas hindlimbs (HLs) more a propulsive one. Within each limb we also assess which limb joints are involved most significantly during braking in the FLs and propulsion in the HLs. Our preliminary results show that average FL braking impulse significantly increases during decline walking (relative to level) and HLs shift to a braking function. During incline walking, FLs produce little to no propulsive impulse while average HL propulsive impulse significantly increases (relative to level). These results illustrate how semi-erect quadrupeds like crocodilians accomplish locomotion across sloped terrain and indicate which limb muscles are likely to contribute to braking and propulsion in alligators. This work expands the range of sloped locomotion to include semi-erect vertebrates and will serve as a foundation for future studies investigating muscle specializations in quadrupedal walkers.

P3-180 ARMFIELD, BA*; CARROLL, A; COHN, MJ; University of Florida; *barmfield@ufl.edu*

Hedgehog Signaling Initiates Genital Tubercle Development

Abnormalities of the external genitalia are among the most common birth defects in humans, affecting approximately 1/250 live births. Development of external genitalia begins with the emergence of paired genital swellings on either side of the embryonic cloaca. The genital swellings then merge to form the genital tubercle, the precursor of the penis and clitoris. Interactions between the endodermal urethral plate epithelium and the surrounding mesenchyme coordinate outgrowth and patterning of the external genitalia. Sonic hedgehog (Shh) is expressed in the urethral epithelium and plays an essential role in the growth of the genital tubercle. Deletion of Sonic hedgehog results in absence of external genitalia in mice, although Shh mutants still form the initial paired genital swellings, indicating that Shh is not required for initiation of genital outgrowth. In a characterization of the transcriptome of the urethral plate epithelium, we found that Indian hedgehog (Ihh), another hedgehog family member, is co-expressed with Shh. To determine if Ihh could compensate for the loss of Shh to promote initiation of genital swellings in Shh mutants, we conditionally deleted both Ihh and Shh in mice. Using 3D imaging (nanoCT) and cell lineage analysis, we found that the double knockout had a more severe genital phenotype than the Shh or Ihh mutants. Specifically, we show that Shh;Ihh homozygous conditional knockouts fail to initiate genital budding and have an expanded cloaca. Comparison of gene expression in Shh/Ihh single and double mutants shows that Ihh can partially compensate for Shh to activate the genital outgrowth circuit. Together these results indicate that coordinated activity of Shh and Ihh is required for initiation of external genital development in mice.

P2-75 ARNONE, A/A*; SATTERLIE , R/A; University of North Carolina Wilmington, University of North Carolina Wilmington ; *aaa7982@uncw.edu*

Innervation of wing musculature by modulatory neurons in the pteropod mollusk Clione limacina

The neural network underlying the locomotory system in *Clione limacina*, a pelagic marine gastropod, is an ideal system for investigating the mechanisms controlling rhythmic motor behaviors. Understanding the organization and modulation of this network is necessary to explain the variations in swimming behavior of this and other animals with rhythmic locomotory movements. *Clione* exhibits four different swimming states including passive sinking (no swimming activity), slow swimming, fast swimming, and startle/escape swimming. These different behaviors are influenced by several biologically active modulatory neurons, as well as by serotonin. Modulatory neurons have been identified in whole mount using immunohistochemical techniques, but we do not know which muscle groups they innervate in the wing tissue. Here we use conventional thick sectioning and electron microscopy to match each modulator with the muscle type found in the *Clione* wing. Light microscopy results indicate that the neuropeptides FMRFamide, SCPb and myomodulin are associated with the smooth retractor muscles, which produce retraction and inhibition of swimming. Similarly, serotonin and the neuropeptide buccalin are associated with the swim musculature.

S12-10 ARZT, E.*; HENSEL, R.; INM - Leibniz Institute for New Materials, Saarbruecken; *eduard.arzt@leibniz-inm.de*

MICROPATTERNED BIO-INSPIRED ADHESIVES - MECHANISTIC INSIGHT AND NEW DESIGNS

The research area of 3D micropatterning of surfaces has matured over the last decade as a means for control of surface functionalities. Due to the large parameter space involved, a clearer quantitative understanding of the adhesion performance of distributed contacts is required for creating reliable adhesive systems. This talk will give an overview of our novel adhesive surfaces with special emphasis on mechanisms and modeling. Starting from the idea of „contact splitting", we have - among others - demonstrated that a switching action to a non-adhesive state can be reproducibly achieved. The numerical simulation of the adhesion performance as a function of materials and structure parameters has allowed us to rationally optimize our structures. Even surfaces with finite roughness are now accessible with our newly designed microstructures. A review has recently been published on these effects and their possible application. The most obvious lack of understanding concerns the cooperative behavior of fibrils during attachment and detachment: most theories consider adhesion of an array to behave like the direct superposition of many fibrils, based on the behavior of one contact. There is considerable new insight to be gained from a direct observation of the contacts. Also, the elastic interaction of fibrils through the backing layer can lead to important effects that need to be understood in order to optimize the adhesion of arrays. Finally, we will present new deformable structures whose unusually high adhesive strengths (in the MPa range) are not fully understood. These and other properties make artificial "gecko surfaces" interesting for creating new surface solutions for robotic pick-and-place systems, assembly machines, in space technology and in biomedicine.

P3-136 ASHLOCK, LW*; PESPENI, MH; University of Vermont; *Lauren.Ashlock@uvm.edu*

Developmental and transgenerational impacts of extreme temperature events in copepods

Acartia tonsa occupy shallow coastal waters, characterized by regular and rapid fluctuations in water temperature. With climate change, mean water temperature and variance in temperature are expected to increase, leading to an increasingly variable environment. While there is evidence that environmental temperature impacts adult thermal tolerance in *A. tonsa*, it is not known if and how extreme temperature events during specific life stages impact adult thermal performance within and across generations. Here, we collected copepods from Penobscot Bay, Maine and allowed them to acclimate to lab conditions for one generation. We then exposed their offspring to short-term extreme temperature events during different stages of development. We assessed adult survival and fecundity of unexposed parents, F1 individuals after developmental temperature treatment, and F2 individuals held under control conditions throughout development. Survival and fecundity assessments were made at a range of temperatures so as to examine the influence of parental and developmental temperature on thermal performance curves. Preliminary results demonstrate that developmental temperature impacts adult thermal tolerance and the impacts of developmental temperature are specific to the life history stage exposed to the extreme temperature event.

134-5 ASSIS, BA*; AVERY, JD; TYLAN, C; EARLEY, RL; LANGKILDE, T; Penn State, University of Alabama; *bmd5458@psu.edu*

Inheritance, Hormonal Drivers and Fitness Implications of Female Ornamentation in Fence Lizards

Flashy secondary sexual traits are uncommon in females of species with traditional sex roles. Such occurrences are often attributed to female inheritance of a phenotype that is adaptive in males, although some evidence suggests that females may also benefit from displaying colorful signals. We investigated maternal inheritance and fitness consequences of male-typical blue badges across three populations of eastern fence lizards, along with potential hormonal drivers of this trait. We measured size and saturation of badges of mothers and their offspring, and relationships between this trait and concentrations of testosterone (T) and baseline corticosterone (CORT). We also assessed potential costs related to honest signaling such as impaired immune function and growth in offspring. There was a positive relationship between saturation of badges of mothers and their female offspring, but not male offspring. The same sex-specific relationship was observed for plasma T levels, which were a strong positive predictor of badge saturation in adulthood for both sexes. CORT levels were negatively associated with badge size, indicating that physiological stress may hinder development of this trait. Maternal badge size was associated positively with offspring immune function. It appears that females inherit their degree of ornamentation from their mothers, but males may be able to develop high-saturated badges independent of maternal phenotype. Despite the positive relationship with T, typical costs of honest signaling and androgens were not detected, and progeny of more ornamented females may in fact be more competitive in certain contexts. Still, other costs of female ornamentation have been detected in this species (e.g. reduced clutch survival), which may contribute to variability among females for this trait.

78-8 ASSIS, VR*; GARDNER, S; SMITH, K/M; GOMES, F/R; MENDONçA, M/T; University of Sao Paulo, Auburn University; *v.regina.a@gmail.com*

Stress, Dispersal, and Immunity: Field Comparisons of the Florida Populations of the Cane Toad

To understand how stress and immunity in cane toads (Rhinella marina) changes throughout the dispersal range in Florida, we measured stress (corticosterone levels [CORT] and neutrophil lymphocyte ratio [NL]) and innate immune parameters (bacterial killing ability [BKA] and natural antibody titers [Ab]) before and after submitting them to a restraint challenge (1h in a plastic bag). When comparing Southern and Northern populations, there were no differences in baseline CORT, NL, or Ab, but BKA was significantly higher in Southern populations ($F_{1,77}=16.8$; $p\leq 0.001$). After restraint, CORT ($F_{1,67}=9.3$; $p=0.003$) and Ab ($F_{1,66}=9.8$, $p=0.003$) differed, with Southern populations exhibiting higher values than Northern ones for both measures. In addition, we calculated the magnitudes of change for each variable and compared between the regions. After the restraint, individuals from the Southern population exhibited larger CORT response than their Northern counterparts (9 fold vs. 3 fold change; $F_{1,67}=5.7$; $p=0.02$). In contrast, NL decreased in Southern toads, while increasing in Northern toads (-13% vs. +26%; $F_{1,62}=4.4$; $p=0.04$) after the restraint challenge. Since the CORT response was higher in the South, we are possibly seeing an immunosuppressive effect on leukocyte redistribution. Additionally, the lower CORT response to the restraint in Northern toads, allowed a more robust change in white blood cell dynamics (possibly a immunostimulatory effect). Southern toads exhibited both, higher baseline BKA and higher post restraint Ab response, when compared with Northern toads which suggests these toads might have a constitutively better surveillance system. We are exploring if there is an energetic tradeoff between immune response and locomotion abilities between the individuals in these populations.

P2-119 ASSIS, VR*; GARDNER, S; GOMES, F/R; MENDONçA, M/T; University of Sao Paulo, Auburn University; *v.regina.a@gmail.com*

Gene Expression of Proinflammatory Cytokines: How are Cane Toads Dealing with Infections under Acute Stress Situations?

The physiological reactions in amphibians to stressors and the consequences of glucocorticoid elevation on their immune responses are still poorly understood. To assess the effects of acute stress on immune reactions in amphibians, invasive cane toads from Florida received either a transdermal application of corticosterone (CORT), the primary glucocorticoid in amphibians, or peanut oil followed by an immune challenge (lipopolysaccharide (LPS) or saline injection; N=6/group). Two hours after the exogenous CORT administration and LPS challenge, we measured the expression of proinflammatory genes (i.e., interleukin (IL) 1β, IL6, IL8, IL12 and tumor necrosis factor alfa (TNFα)), as well as plasma CORT and plasma bacterial killing ability (BKA). CORT levels were significantly higher in animals in the CORT+LPS treatment when compared to the Oil+Saline (Control) group as well as the Oil+LPS treatment ($F_{2,12}=33.466$; $p\leq 0.001$). BKA was higher in Control animals ($F_{2,12}=6.741$; $p=0.008$) when compared to Oil+LPS and CORT+LPS. There was upregulation in 3 of the 5 pro-inflammatory genes investigated on the LPS+CORT animals compared with Controls: IL1β was upregulated by log2fold factor of 4 ($p=0.018$); IL6 upregulated by log2fold factor 4.8 ($p=0.005$); and IL8 upregulated by log2fold factor 4.7 ($p=0.018$). Thus, LPS alone didn't trigger a significant change in gene expression, but the combination of LPS and acute increase in circulating CORT caused by the exogenous CORT administration stimulated the immune response. The multiple immune genes being upregulated have different roles, including phagocytic stimulation. These results may warrant investigation to whether CORT alone triggers differentially expressed immune genes in cane toads.

68-7 ASTLEY, H. C.*; SIDDIQUI, H. K.; LAREDO, D.; University of Akron, Denison University, Carnegie Mellon University; *hastley@uakron.edu*

High Hysteretic Energy Loss in Mouse Tendons

Tendons play a crucial role in vertebrate locomotion, functioning as springs which allow elastic energy storage and release. Consequently, these biological springs can function in power amplification during accelerations, power attenuation during decelerations and recycling energy within a stride during steady, level running. These functions are aided by low hysteresis of the loading-unloading curve, with 90% or more of energy stored in the tendon being returned during unloading. During loading, tendons initially have a low-stiffness "toe region", followed by a high-stiffness linear region, each mediated by different processes. To determine whether hysteresis varies with strain and frequency, we isolated mouse Achilles tendons and subjected them to sinusoidal length changes while recording force. Both strain and frequency had minimal effects on hysteresis, but hysteretic energy losses were consistently high, with between 35-45% of the loaded energy being lost. This high hysteretic energy loss differs tremendously from the <10% loss seen in other species. Replication of methods on rubber samples showed 10% low energy loss, and there was no evidence of knot slip, fatigue or damage during the trials. In subsequent replication experiments, ink marks on the tendon were tracked via video, but no strain heterogeneity was observed. Similar results have been published by other labs for mouse Achilles and tibialis anterior tendons and rat tail tendons. Such large hysteretic losses may contribute to the limited use of elastic energy storage in rodents during locomotion.

P3-68 ATKINS, EL*; TINHAN, TC; WELLS, RJD; ALVARADO-BREMER, JR; Texas A&M University Galveston ; *ericaknowles@tamu.edu*

Estimating levels of gene flow of a large coastal shark, Carcharhinus leucas, in the Gulf of Mexico

Population structure of the Bull Shark (*Carcharhinus leucas*) in the Gulf of Mexico (GOM) was examined using genetic and genomic data. Tissue samples were collected throughout the GOM, along with the inclusion of reference samples from the western Pacific and Caribbean Sea. Since *C. leucas* is believed to exhibit female philopatric behavior towards their natal site, we characterized the patterns of variation in the mitochondrial DNA (mtDNA) genome by inferring the phylogenetic relationships of representative samples using mtDNA control region (CR) sequences. The results suggest the population in the GOM has lower haplotypic diversity than those in the Caribbean Sea and in the western Pacific. To determine whether sex-biased dispersal exists, we also examined variation in the nuclear genome by characterizing single nucleotide polymorphisms (SNPs) using double digest restriction based DNA (ddRAD) sequencing. We discuss the inferred patterns of migratory behavior and levels of gene flow within and between the GOM, Caribbean Sea, and the Pacific using both mtDNA and genomic data.

P2-62 AULETTA, A*; MESCE, KA; Univ. of Minnesota, Twin Cities; *aulet002@umn.edu*

An Examination of Biogenic Amines in the Nervous System of the Scorpion Centruroides sculpturatus (Scorpiones: Buthidae): Insights Into the Evolution of Neural Signaling in the Arthropoda

Underlying the exquisite diversity of complex arthropod behaviors are intricate neuromodulatory systems that can finely adjust those behaviors to meet specific demands. Although such systems are well described in some arthropod groups, they are poorly known in others, including the subphylum Chelicerata. Since the Chelicerata are the most basal of extant arthropod groups, a better understanding of their neuromodulatory systems is key for determining how complex modulatory systems evolved within the Arthropoda as a whole. We have investigated the presence, distribution, and functions of several behaviorally important neuromodulators—the catecholamines (dopamine and norepinephrine) and octopamine— in a representative chelicerate, the scorpion *Centruroides sculpturatus* (Scorpiones: Buthidae). We have localized catecholaminergic and octopaminergic neurons in the CNS of the scorpion via immunocytochemistry, and quantified levels of catecholamines in the CNS via ultra-performance liquid chromatography-mass spectrometry. Using recently available genomic data for *C. sculpturatus*, we also identified putative genes and transcripts for enzymes in catecholamine and octopamine biosynthesis, as well as receptors for these modulators. In addition, extracellular electrophysiological recordings indicate that catecholamines and octopamine elicit different physiological responses in the scorpion, which may underlie distinct behavioral programs not yet fully understood. When compared to data from other organisms, our results suggest that chelicerates may retain several ancient features of neuromodulatory systems thought to have been present in the common ancestor of Bilaterian animals, but lost in other arthropods.

14-5 AUSTIN, S.H.*; LANG, A.S.; MACMANES, M; CALISI, R.M.; UC Davis, University of New Hampshire; *shaustin@ucdavis.edu*

What to expect, when you're expecting to become parents? Genome to phenome changes in reproduction of rock doves (Columba livia)

The transition to reproduction requires major changes in the physiology and behavior of an organism. Research continues to elucidate crucial endocrine players and pathways associated with this fundamental transition to reproduction yet we know less about the underlying genomic activity that drives these behaviors. Using the rock dove (*Columba livia*), a socially monogamous species with biparental care, we ask, are the genetic mechanisms that facilitate similar behaviors in males and females the same across sex, or do they differ? Conversely, is the genomic origin of sex-specific behaviors the same or different? We also seek to determine key genes associated with transitions using phenotypic manipulations that test the role the interplay between offspring cues compared with biological schedule during reproduction. To address these questions, we used high-throughput sequencing to determine sex-biased differences in gene activity over the course of reproduction. At nine different time points that range from non-breeding through to neonate care, and 7 manipulations, we assessed levels of gene transcription in tissues critical for reproduction in vertebrates: the hypothalamus and lateral septum in the brain, the pituitary gland, and the gonads. We found a diversity of similar and sex-biased changes in gene expression across reproduction and in response to manipulations. The results of this large-scale study offer significant insight into the genomic mechanisms driving male and female reproductive behaviors, from genome to phenome.

132-3 AUSTIN, MD*; FELDMANN, S; DUNLAP, AS; Univ. of Missouri, St. Louis; *mdaf2b@mail.umsl.edu*

Are Smart Flies Off the Menu? The Effect of Evolved Learning Ability on Survival Under Predation

A large degree of individual variation in learning ability has been shown to exist in natural populations of many animals; including birds, mammals and insects. Learning ability is heritable and can be rapidly increased through artificial selection and experimental evolution in natural and laboratory environments. This suggests that the observed individual variability in this trait is maintained through a balancing of the costs and benefits of enhanced cognition. Enhanced learning ability could theoretically benefit an animal by facilitating better retention of salient information, by increasing the chances of successful innovation or by allowing for increased survival under conditions of high predation. The costs of increased learning can be developmental, operational or syndromic (e.g. learning-adept individuals could be more prone to sample dangerous environments, increasing sensitivity to predation). As part of a separate experiment investigating the effect of environmental change on the evolution of learning, we evolved replicate populations of *Drosophila melanogaster* that display enhanced learning ability across a suite of contexts when compared to lab-reared controls. We conducted two experiments to test responses to predation in these populations and their controls. In the first experiment, we filmed individuals from each population type while in the presence of a mantis predator (*Tenodera sinensis*) and measured fly casualties and avoidance behaviors over time. In the second experiment, we labeled individuals from each population and measured their survival after 3 hours in the presence of the predator. We present data from these experiments to show the effect of learning ability on survival under predation. Our experiments add to our empirical understanding of the costs and benefits of learning ability and of the maintenance of individual variation in this trait in natural populations.

P3-88 AWALI, S*; ABDULELAH, SA; CRILE, KG; YACOO, KE; TORRES, VC; DAYFIELD, DJ; ALMOUSELI, A; EVANS, KR; BELANGER, RM; University of Detroit Mercy; *awalisa@udmercy.edu*

Exposure to environmentally-relevant concentrations of atrazine causes changes in cytochrome P450 and glutathione-S-transferase activity in the hepatopancreas of crayfish (Faxonius virilis)

The herbicide atrazine is commonly applied to crops in the U.S. Midwest in order to control broad leaf weeds. Atrazine enters local streams and rivers through runoff, seepage, evaporation and regional transport, subsequently affecting aquatic organisms. To examine the effects of atrazine on expression and activity levels of the oxidative enzymes cytochrome P450 (CYP1A1) and glutathione-S-transferase (GST), we used the used the keystone species crayfish as a bioindicator. Crayfish were treated with 0, 10, 40, 80, 100 and 300 ppb atrazine for 1, 2, 4, 7 and 10 days. According to results, there was a significant increase in CYP1A1 expression levels succeeding treatments of 100 ppb for one day, 10 ppb for two days, and 40 ppb for four and ten days. At seven days of exposure, there were no significant differences of CYP1A1 expression levels for all concentrations. Moreover, our results indicate a significant increase in GST expression following treatments of 300 ppb for one, two, four, seven, and ten days, as well as 10 ppb for two days. Overall, detoxification enzyme expression and activity levels are affected following environmentally-relevant exposures of atrazine. Exposure to atrazine may ultimately lead to increased energy demands and alter population fitness.

P1-251 AWBREY, JD*; FRANCE, SC; University of Louisiana at Lafayette; *jawbrey@louisiana.edu*

Evolution of the Octocorallian Family Acanthogorgiidae (Gray 1857)

Acanthogorgiidae (Gray, 1859) are a family of sea fans found throughout the oceans and at a wide range of depths. The family comprises about 130 species, currently divided among 5 genera. No phylogenetic analysis of Acanthogorgiidae has previously been conducted, although inclusion of some species in broader analyses of the Octocorallia suggest the family is not monophyletic. Here we provide a first explicit phylogenetic examination of the family to test for monophyly and to better understand their evolution and taxonomy. Sequences from the mitochondrial MutS gene were collected from 4 of the 5 acanthogorgiid genera and added to a dataset of 86 GenBank sequences from acanthogorgiids and several GenBank sequences representing other families of holaxonian octocorals and analyzed using both Maximum Likelihood and Bayesian Inference methods. The results of these analyses will be discussed in detail.

P2-71 AYALI, A*; TALAL, S; GEFEN, E; Tel Aviv University, University of Haifa-Oranim; *ayali@post.tau.ac.il*

Interactions Between Carbon Dioxide and Oxygen Sensing in the Control of Locust Ventilatory Pattern Generation

Insects exchange respiratory gases through an extensive network of tracheae that open to the surface of the body via segmental spiracles. In actively ventilating insects, such as the locust, respiration involves the well-coordinated activity of spiracular muscles and ventilatory muscles, responsible for abdominal pumping movements. Our previously reported data indicated a strong coupling between the spiracular and the ventilation pattern generating circuits (CPG), and provided insights into their modulation by concentrations of respiratory gases. Here, we directly tested the interactions between CO_2 and O_2 sensing in the control of the locust ventilatory motor patterns through *in-vitro* isolation of the thoracic ganglia, where ventilatory CPG are located, and their associated main tracheae. We perfused the main tracheae with various gases mixtures while recording the rhythmic activity from the motor nerves controlling spiracle and ventilatory muscles. Initially, using aerated saline we recorded no change in the fictive ventilatory activity to increasing tracheal CO_2 levels (at 6% O_2) within the physiologically relevant range. In contrast, when the saline was bubbled with 6% O_2 in N_2 (or in anoxic saline), a significant increase was recorded at 3.5% CO_2, indicating a role for hemolymph gas concentration. Reducing tracheal O_2 levels (in 0% CO_2) resulted in significantly increased ventilatory activity only at 2% O_2. However, the response to 3.5% CO_2 was significantly higher at tracheal levels of 3% O_2, and lower at 9% O_2, compared with 6% O_2. Furthermore, efferent ventilatory output increased 3-fold at 2% O_2 and 2% CO_2, whereas 2% O_2 alone caused a 20% increase only and 2% CO_2 alone did not elicit any response. Together, these findings indicate central sensing of both respiratory gases, and interaction in their effects on respiratory output from the CNS.

111-5 AYALI, A*; KNEBEL, D; GUERSHON, M; ARIEL, G; Tel Aviv University, Tel Aviv, Israel, Bar Ilan University, Ramat-Gan, Israel; *ayali@post.tau.ac.il*

Interactions Between Individual and Group Variance in Collective Behavior

Animal collective behavior is a result of the intricate conflict between the natural variability among the individuals comprising a group, and the homogenizing effect of the group, working to generate synchronization and maintain coherence. Deciphering the bi-directional interactions between individual and group properties is essential for understanding the swarm phenomenon. Here, these conflicting, complex interactions were studied using marching locust nymphs under controlled laboratory settings. Novel experimental and analysis methods were applied to compare single animals, small groups of locusts, and virtual groups composed of real, randomly shuffled and thus non-interacting, members. This unique approach revealed two types of behavioral characteristics: 1) Traits that were under the homogenizing effect of the group, i.e. differing between single animals and groups, but not between group types. These traits were classified as essential for the formation of the swarm and the collective behavior; and 2) Traits retaining individual heterogeneity. These were responsible for the distinctive, group-specific behavioral characteristics, reflected in large inter-group and small intra-group variance (when compared to the virtual groups). Markov-chain models were used to identify social interaction networks within the group, as well as to confirm the hypothesized interplay between variance at the individual level and the emerging group-specific behavioral properties.

S4-5 AYDIN, YO; CULVER, J; TENNENBAUM, M; GOLDMAN, DI; BHAMLA, MS*; Georgia Institute of Technology; *saadb@gatech.edu*

Dynamics of a worm blob

Organisms across all length scales (from cells to humans) cluster and forms large social groups for evolutionary advantages. In some cases, aggregates exhibit and enable new functionalities: floating on water (fire ants), nest-building (bees) and mobbing predators (birds). In this talk, we describe new insight into aggregation behavior in worms, where hundreds of thousands of worms entangle together to form a large, wet, and squishy 'blob'. These worm blobs have emergent viscoelastic properties of the collective - they can flow through tubes, while bouncing off hard substrates; they can 'sense' each other and merge; they can rapidly unknot and dissipate into individual units within a few seconds; and lastly the worm blob as a whole can break symmetry and move across substrates in response to external gradients.

95-3 AZZOLINI, JL*; DENARDO, DF; Arizona State University; *jlazzoli@asu.edu*

Effect of Reproduction on Female Oxidative State and the Potential for Vertical Transfer to Offspring

Oxidative stress physiology has historically received attention in regards to medicine and nutrition. However, recent studies suggest that life history strategies of aerobic organisms may be constrained by tradeoffs between energetically costly activity (e.g., growth and reproduction) and maintaining oxidative balance. Oxidative balance refers to a state when antioxidant defenses are capable of neutralizing the negative effects of free radicals known as reactive oxygen species (ROS). In contrast, oxidative stress occurs when there is an imbalance between ROS and antioxidants, and cells accumulate oxidative damage. Using Children's pythons (*Antaresia childreni*), I tested the hypotheses that: (1) the tradeoff between oxidative state and reproduction is stage dependent with stages that have greater energetic cost imposing greater oxidative stress, and (2) maternal oxidative state influences the oxidative state of her eggs. I serially measured ROS and antioxidants in the blood of 30 female *A. childreni* during late vitellogenesis, just prior to oviposition, and when non-reproductive. These timepoints represent peak energetic investment by the mother, the end of reproductive investment, and a non-energetically costly life history phase, respectively. I explored the potential for vertical transfer of maternal oxidative state to offspring by comparing female oxidative state to that of her eggs at oviposition and at day 39 of incubation, just prior to hatching. The results from this study will provide insight into the notion that reproduction imposes oxidative costs to both the mother and her offspring.

P1-93 AZZOLINI, JL*; DENARDO, DF; Arizona State University; *jlazzoli@asu.edu*

Effects of Chronic Water-Deprivation on Oxidative State in a Drought-Tolerant Snake

Many environmental stressors, including hypoxia, anoxia, ecotourism, and temperature fluctuations, have recently been analyzed in the context of how they impact oxidative state. Studies have found that these stressors can, in fact, impose oxidative stress. However, despite the physiological importance of water, the effect of dehydration, a common environmental stressor for species that undergo seasonal droughts, on oxidative state has largely been unexplored. We chose to investigate the effect of water deprivation on oxidative state using Children's pythons (*Antaresia childreni*), which are native to Northern Australia and experience yearly dry seasons. Children's python become dehydrated at times during the dry season and dehydration improves innate immune performance, leading to our question of whether dehydration might also affect oxidative state. We collected a blood sample from 15 male Children's pythons at the start of the study when they were hydrated, then subjected them to 52 days without food or water, a duration that is ecologically relevant. After 52 days, we collected a second blood sample to ascertain the effect of dehydration on oxidative balance. We then provided them with water *ad libitum*, and collected blood samples at 3 and 7 days post re-hydration to ascertain the timing of recovery from the dehydration event. Our work provides foundational results that enable us to begin to understand the relationship between water balance and oxidative state.

23-2 BABONIS, LS*; MARTINDALE, MQ; Univ of Florida, Whitney Lab; *babonis@whitney.ufl.edu*

Double your fun: gene duplication and the diversification of novel cell types

The question of how novelty arises has lurked in the background of evolutionary biology for decades. One common hypothesis suggests that novel traits arise with the origin of novel genes. Support for this 'novel genes-novel traits' hypothesis largely comes from studies that have identified taxon-restricted genes (which lack identifiable orthologs outside of the taxon of interest) as critical regulators of novel trait identity. A clear example supporting this argument is the role of minicollagen, a cnidarian-specific protein, in the development of the cnidocyte (stinging cell); but examples such as these are rare. We take a different approach to this question; specifically, we examine the role of lineage-specific duplications of conserved gene families on the development and diversification of cnidocytes from the sea anemone *Nematostella vectensis*. Using functional and comparative genomics and phylogenetics, we show that different cnidocyte types express unique assemblages of paralogs of common/shared genes. Further, we provide evidence that duplication and diversification of effector genes (rather than transcription factors) may play a critical role in supporting the diversification of cell identity. Together, our results imply that general orthology analysis might fail to accurately characterize the transcriptional environment of similar cell types and may, therefore, underestimate the role of gene duplication in facilitating cell diversification.

40-8 BADE, LM*; SCHERR, MP; ANGELINI, DR; Colby College; *lyndell.bade@colby.edu*

"What's for Dinner?" Use of high-throughput sequencing to illuminate cownose ray feeding ecology and diet composition.

Cownose rays, *Rhinoptera bonasus*, are highly migratory elasmobranchs native to the Western Atlantic and Gulf of Mexico. Cownose rays are known to feed predominantly on mollusks and crustaceans, but it is still unclear which species are most commonly consumed. Cownose rays are durophagous feeders, crushing their prey, making it difficult or impossible to identify stomach contents. Fieldwork conducted from 2010 to 2013 collected gut samples from cownose rays in Pamlico Sound, North Carolina, and Chesapeake Bay, Virginia (Bade 2013). Among these samples, 80% of stomach contents (by mass) could not be identified by visual inspection, and in spiral valves (intestines) the total unknown tissue was 95%. Even when prey items are crushed and anatomical identification is impossible, DNA in gut contents can be sequenced to establish connections between predators and prey. This study sequenced DNA from digestive tracts of the 33 cownose rays previously studied, as well as another 22 rays from Chesapeake Bay. The *cytochrome oxidase I (COI)* and *16S* gene were targeted to better understand diet composition of cownose rays, even at different stages of digestion, and gut microbiome composition. Targeted amplification and high-throughput sequencing of barcoding genes holds the potential to transform our understanding of trophic connections in communities that are inaccessible and where traditional observations are costly or dangerous. A more thorough understanding of the feeding ecology of cownose rays will provide critical information for fisheries management and conservation.

45-6 BADGER, MA*; COMBES, SA; Univ. of California, Davis;
mbadger@ucdavis.edu

MegaTracks: Deep learning methods enable rapid, automated tracking of complex motion sequences

Deep learning is a method by which complex mathematical functions such as artificial neural networks are trained to make accurate predictions using a limited set of examples. Deep learning has proven wildly successful for tasks ranging from object detection to control of self-driving cars and has the potential to eliminate the need for extensive manual video digitization, which is one of the slowest bottlenecks in studies of animal behavior and biomechanics. Motivated by the growing availability of frameworks (e.g. Keras) to more easily construct and train neural networks, we tested these methods on the task of tracking six points on the body and wings of freely maneuvering blue orchard bees (*Osmia lignaria*) as they carried mud loads during nest construction. We filmed 43 flights of seven individuals and manually annotated 11 flapping cycles in each video to obtain ~10,000 training images across two camera views. Once trained, we deployed our network on 113 trials to automatically track six points in ~183,000 frames across 212 continuous flight segments, with a median of 32 tracked wing strokes per segment. Neural network predictions were robust to shadows and focus blur, and reprojection error of triangulated points (2% of wing length) was comparable to that of manually digitized data. We examined how the number of training examples and their allocation among individuals and trials affected neural network tracking performance. Finally, we explored the effect of mud loading on the relationship between fast wing motions and slower body dynamics during flight maneuvers. Deep learning methods greatly improve the speed and consistency with which data are extracted from long videos and allow us to unravel processes operating at multiple timescales over complex behavioral sequences.

S4-12 BAER, A; SCHMIDT, S; MAYER, G; HARRINGTON, MJ*; University of Kassel, Germany, Heinrich-Heine-Universität, Düsseldorf, Germany, McGill University, Montreal, Canada;
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Fibers on the Fly: Multiscale Mechanisms of Fiber Formation in the Capture Slime of Onychophorans

Many organisms evolved a capacity to form biopolymeric fibers outside their bodies for adaptive functions such as defense, prey capture, attachment and protection. In particular, the adhesive capture slime of velvet worms (Onychophora) is remarkable for its ability to rapidly form stiff fibers through mechanical drawing. Notably, fibers formed ex vivo from extracted slime can be dissolved in water and new fibers can be drawn from the solution, indicating that fiber formation is encoded in the biomolecules that comprise the slime. This talk presents recent findings on the biochemical and physicochemical principles guiding this process. Employing a multiscale cross-disciplinary approach utilizing techniques from biology, biochemistry, physical chemistry and materials science, we determined that the slime is a concentrated emulsion of nanoglobules comprised of proteins and lipids, stabilized via electrostatic interactions. Upon mechanical agitation, globules break apart, leading to spontaneous self-assembly and fibrillation of proteins - a completely reversible process. Recent investigations highlight the importance of subtle transitions in protein structure and charge balance. Our findings have clear relevance for understanding the evolutionary success of this adaptive prey capture behavior and for providing inspiration towards sustainable polymer processing.

S4-4 BAGGE, LE*; KINSEY, ST; KIER, WM; JOHNSEN, S; Duke, Univ. of NC Wilmington, Univ. of NC at Chapel Hill;
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Clearly Camouflaged: Ultrastructural Modifications in Transparent Animals

The 'superpower' of invisibility is a reality and a necessity for many animals that live in featureless environments like the open ocean, where there is nowhere to hide. How do animals achieve invisibility? Many animals match their color patterns to their background, but this strategy is limited when the background scene is dynamic. Transparency, however, allows organisms to match any background all the time. It is unclear how clear crustaceans with complex bodies (i.e. with hard cuticles, thick muscles, and internal organs) maintain transparency across their entire body volume. Transparent crustacean species that have relatively large (> 25 mm long and > 2 mm thick) bodies and that occupy physically different (pelagic vs. benthic reef) habitats serve as useful model organisms. Making comparisons between these transparent crustaceans and closely related opaque crustaceans provides some of the first insights into the physical basis of transparency, from nano-scale to organismal-scale. I will discuss how light scattering can be minimized both at an animal's surface and internally, as well as whether transparency can be disrupted and what the underlying mechanisms of this disruption are. A variety of microscopy techniques were used to investigate the ultrastructure of transparent animals. We found multiple unique adaptations, such as anti-reflective nanostructures on the exterior cuticle surfaces of certain crustaceans. In addition, we found adaptations for minimizing interior light scattering, such as differences in myofibrillar diameters (i.e. differences in number of scattering interfaces) as well as differences in blood perfusion between transparent and opaque species, suggesting there may be tradeoffs to transparency.

64-6 BAGHERI, H; JAYANETTI, V*; BURCH, HR; BRENNER, CE; ARNOLD, JK; MARVI, H; Arizona State University;
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A Bio-Inspired Robot for Locomotion on Dry and Wet Granular Media

The basilisk lizard is a highly agile reptile with the ability to traverse on vast, alternating, unstructured, and complex terrains (i.e. sand, mud, and water). This makes them a great model organism for pursuing potential solutions for robotic locomotion on such terrains. Through our animal experiments of the brown basilisk lizard on granular media, it was discovered that the animal's body velocity increased as the sand's saturation level increased from 0% to 30%. To interpret the increased body velocity, the limb frequency and stride length of the animal were evaluated. It was observed that while limb frequency remained relatively consistent, the stride length increased as the saturation increased from 0% to 30%. To systematically evaluate the influence of limb frequency and stride length on body velocity, the BasiliskBot was designed and tested upon the same medium, against 0%, 15%, and 30% saturated sand. Limb frequency was adjusted by altering the motor speed, and stride length was modified through the utilization of different whegs with varying number of spokes. As the saturation increased from 0% to 30%, so did the stride length and stride frequency and thus the body velocity. In addition, increasing the stride frequency and saturation resulted in decreasing the robot's cost of transport. The hierarchical concepts observed and learnt through animal and robotic experiments can be used towards designing, modeling and developing robotic systems with the capability to traverse over complex and unstructured terrains.

31-2 BAGHERI, H*; CUMMINGS, S; ROY, C; CASLETON, R; WAN, A; HU, A; BERMAN, SM; PEET, MM; AUKES, DM; HE, X ; FISHER, RE; MARVI, H; Arizona State University, University of California, Los Angeles, University of Arizona College of Medicine-Phoenix; *hbagheri@asu.edu*

Octopus Suckers: Functionality and Control

The octopus, with its soft, muscular hydrostat body and arms, is proficient in locomotion and complex motor functions. Their versatility, "infinite" degrees of freedom, and dexterity have made them an inspiration for soft robotics and synthetic adhesion mechanisms. Octopus suckers have been observed to be utilized for body anchoring, swift maneuvering, object examination and manipulation, and chemo and tactile sensing. Most of these tasks would be impossible without the sucker's main functionality, the attachment mechanism. This study was designed to determine: (1) how much of the attachment mechanism depends on suction versus adhesion, (2) if pull-off force varies in different arms (i.e. anterior and posterior arms), and (3) how pull-off force is impacted if there is no communication with the brain. While these parameters may have been qualitatively described in previous studies, they have never been addressed quantitatively. Experiments were conducted on ten *Octopus bimaculoides* (five female and five male). Pull-off force was measured on intact arms, amputated arms, and amputated arms with punctured sucker to gain insights into sucker functionality and control mechanisms. The results of these experiments can be used to design efficient synthetic underwater attachment mechanisms. Coupled with soft robotic arms, these synthetic "suckers" can be utilized to maneuver on and through aquatic environments for exploration and environmental monitoring.

107-4 BAKER, D.M.; BAKER, Dianne; University of Mary Washington; *dbaker2@umw.edu*

Redesign of an undergraduate endocrinology course to incorporate authentic research

The Department of Biological Sciences at University of Mary Washington has greatly modified our curriculum to meet the recommendations proscribed in the AAAS report, "Vision and Change in Undergraduate Education." Our most significant changes have been to include authentic research experiences throughout the core curriculum and to require completion of one of several new "Research Intensive" (RI) courses, each based on a different biological subdiscipline. The RI courses share common learning objectives concerning experimental design, data analysis, and scientific communication, but differ in content-specific objectives. I recently converted a traditional comparative endocrinology to an RI course, "Research in Endocrinology." After a primer on general endocrinology principles and methods, students shifted focus to more deeply examine the stress hormone axis through primary literature. Students then designed, conducted, and analyzed experiments to test their hypotheses on some aspect of the stress axis or stress response, using zebrafish as a model organism. Finally, students wrote journal article-style manuscripts and delivered oral or poster presentations of their studies. I will discuss details of this course model, as well as both the benefits and challenges of this shift in course emphasis from content to process.

92-4 BALEBAIL, S*; RAJA, S.K.; SANE, S.P.; National Centre for Biological Sciences, TIFR; *sane@ncbs.res.in*

Landing behavior on vertical vs. inverted substrates by flies

Landing maneuvers in flies may be decomposed into a sequence of modular behaviors such as body deceleration, extension of legs, and body rotations to ensure that the body is parallel to the landing substrate during touchdown. The variability in the conduct of landing maneuvers makes it difficult to identify the general rules that govern this behavior. Previous studies have relied on tethered preparations to study landing behaviors, but tethering constrains some behavioral modules to operate in an open feedback control loop while others remain in closed-loop, causing experimental artefacts. On the other hand, freely flying insects are hard to precisely control causing behavioral variability that is difficult to control. We elicited landing behaviors in houseflies (*Musca Domestica*) on vertical or inverted horizontal substrates, which could be captured accurately using multiple high-speed video cameras. Our experiments show that flies land in a smooth and controlled manner if they satisfy specific criteria. Flies landing on the vertical surface and those landing smoothly on the inverted surface initiated deceleration at fixed distances from the substrate, in direct proportion to the component of flight velocity normal to the landing surface. The ratio of distance to perpendicular velocity at the onset of deceleration was conserved, despite large differences in the mechanics of the vertical vs. inverted landings. Flies extended their legs independently of distance from the landing surface, and the component of approach velocity normal to the surface, regardless of the orientation of the landing substrate. Together, our results suggest that the visual initiation of deceleration is robust to orientation of the landing surface.

39-5 BALENGER, S.L.; Univ. of Mississippi; *balenger@olemiss.edu*

Costs associated with Mycoplasma gallisepticum infection of Eastern Bluebirds (Sialia sialis)

Mycoplasma gallisepticum (MG) is a respiratory pathogen that induces swelling of the conjunctival mucous membrane lining the eye in domestic poultry and wild finches. Although experimental infection studies generally focuse on conjunctivitis as the primary physical symptom of interest, wild bird surveys suggest that many additional avian species function as carriers and potential reservoirs for MG spread. Due to a lack of obvious conjunctivitis symptoms, however, infection costs to these hosts have as of yet been largely unstudied. In 2017, 40% of wild-caught adult Eastern Bluebirds (*Sialia sialis*) in a Mississippi population tested positive for MG-specific Abs. To determine whether infection with MG is costly to this host species, I infected wild-caught, captive Eastern Bluebirds with a strain of MG cultured from a wild House Finch (*Haemorhous mexicanus*). Importantly, while no animals developed conjunctivitis symptoms over the course of the experiment, 12% of infected birds died before the experiment was complete. Following inoculation, 56% of birds seroconverted within 13 days, and MG was re-cultured from 25% of infected birds. In general, infection resulted in splenomegaly and significant weight loss. Infected birds that seroconverted were in better body condition and had higher levels of circulating corticosterone than those that did not seroconvert. Results strongly suggest that Eastern Bluebirds are not only common MG hosts in the wild, but that they suffer physiological and survival costs in response to infection with this common natural pathogen.

138-3 BALIGA, VB*; SZABO, I; ALTSHULER, DL; University of British Columbia, Vancouver; *vbaliga@zoology.ubc.ca*
Range of motion in the avian wing reflects evolutionary specialization for different flight behaviors
Birds can actively change the shape of their wings, an ability termed "wing morphing", which allows for manipulation of mechanical forces and moments. Birds also exhibit substantial differences in wing skeletal morphology, but it is unknown how these anatomical differences affect the range of motion in the wing or whether such patterns are driven by specializations for flight, allometric scaling, or phylogenetic history. We performed a functional anatomical study of range of motion using cadavers of 61 species representing 20 avian orders. Through a multi-camera setup, we recorded for each species the capability of three types of motion at skeletal joints: 1) extension or flexion, 2) elevation or depression (bending), and 3) pronation or supination (twisting). For all taxa, the range of motion of the wing is highly position-dependent with reduced freedom of movement as the wing is extended. Traditional ‘static' morphometrics, including wing shape at full extension, show high phylogenetic signal and poor associations with flight behaviors or body mass. Range of motion data, however, show flight- and body mass-specific patterns along with relatively low phylogenetic signal. In particular, species that are more prone to gliding, soaring, and/or swimming underwater with their wings show more drastic constraints to range of motion. Collectively, our data demonstrate that avian wing morphing capability has a dynamic evolutionary history that shows stronger concordance with flight style and body mass than does a more traditional view of wing shape.

S7-8 BALIGA, VB*; MEHTA, RS; University of British Columbia, Vancouver, Univ. of California, Santa Cruz; *vbaliga@zoology.ubc.ca*
Macroevolutionary insights from independent origins of cleaning behavior around the world: synthesizing morphology, ecology and biogeographic patterns
Members of an ecological guild may be expected to show morphological convergence, as similar functional demands may exert similar selective pressures on phenotypes. Nature is rife with examples, however, where taxa may instead exhibit ‘incomplete' convergence or even divergence. Incorporating additional factors such as competitive displacement from other guild members or variation in ecological specialization itself may therefore be necessary to gain a more complete understanding of the factors that constrain or promote diversity. Cleaning, a behavior in which species remove and consume ectoparasites from ‘clientele', has been shown to exhibit variation in specialization and has evolved in a variety of marine habitats around the globe. We use the evolution of cleaning behavior in clades within five marine fish families, Labridae, Gobiidae, Pomacanthidae, Pomacentridae, and Embiotocidae, to determine the extent to which both specialization in this tropic strategy and biogeographic overlap has affected phenotypic evolution. Here, we use a comparative geometric morphometric framework to showcase patterns of convergence and divergence in body shape and size across non-cleaning and cleaning members within these five clades. Focusing chiefly on two regions, the Indo-Pacific and the Caribbean, we find that the highly specialized, obligate cleaning evolves early, shows highly convergent morphological patterns, and is restricted to species of small body size. Facultative cleaning is a relatively younger behavior that shows a much more varied pattern, especially in geographic regions where obligate cleaning is already present.

P2-190 BALLARD, E.J.*; BARRETT, L.M.; DEAROLF, J.L.; THOMETZ, N.M.; BRYAN, A.; REICHMUTH, C.; Hendrix College, Conway, AR, Univ. of San Francisco, CA, Alaska Dept. of Fish and Game, Fairbanks, Univ. of California, Santa Cruz; *ballardee@hendrix.edu*
Hybrid fibers in the bearded seal longissimus dorsi muscle
Bearded seals (*Erignathus barbatus*) are shallow diving pinnipeds that mostly stay in depths of about 100 meters or less. Being benthic feeders, they scour the ocean floor searching for food sources like polar cod, sculpins, shrimp, spider crabs, and a variety of other invertebrate species. Their benthic habits are a unique aspect of the life of bearded seals in the Arctic, which makes their diving ability an interesting topic of study. Specifically, understanding the physiology of bearded seal locomotor muscle could provide key insights into these abilities. Thus, the goal of this study was to quantify the percentages of hybrid fibers, fibers expressing more than one myosin heavy chain, in the longissimus dorsi (LD) of bearded seals. To achieve this goal, samples of bearded seal LDs were stained for their myosin ATPase activity after alkaline pre-incubation and their reaction to two myosin heavy chain antibodies: SC-71 (type IIA - fast-twitch oxidative-glycolytic), and A4.951(type 1 - slow twitch). Then, images were taken from identical regions in each of these samples using a Zeiss Axio Imager AI microscope and AxioVision v. 4.7 software. On the images, we identified slow- and fast-twitch fibers that were staining for both A4.951 and SC-71 and determined the percentages of these fibers in the LDs of the seals. Using ImageJ, we also measured the diameters of both types of hybrid fibers. From these data, we calculated overall averages of the percentages and diameters of the slow and fast-twitch hybrid fibers. Studying the hybrid fibers in the LDs of bearded seals will give us valuable insight into the unique diving abilities of the bearded seal.

P3-6 BALLENTINE, WM*; DORGAN, KM; University of South Alabama, Dauphin Island Sea Lab; *wballentine@disl.org*
Effects of Infauna on Sound Speed and Attenuation in Marine Sediments
Infauna alter the physical properties of marine sediments in many ways. Compact mud burrows, tubes built from shell hash, large subsurface galleries, and local changes in porosity are a few examples of these alterations. Structural changes such as these may be detectable non-invasively through their effects on the acoustic properties of sediment. Here, we investigate how infauna may affect the sound speed and attenuation in sediments using laboratory mesocosm experiments with controlled manipulations. These manipulations are intended to mimic how potentially important functional groups of infauna affect sediment structure while minimizing the variability inherent in working with live animals. In both manipulated and control mesocosms, sound speed and attenuation were measured at multiple depths and at high frequencies (100-400 kHz) with wavelengths (4-15 mm) corresponding to the scales of expected impacts of individual infaunal organisms. Manipulations include construction of tubes from shell hash to mimic *Owenia* polychaete tubes, burrowing via excavation and compaction, and sediment irrigation. Physical obstructions, like a shelly tube, were the most easily detectable manipulations, although irrigation and burrowing were still detected at higher frequencies.

P3-142 BALLINGER, MA*; TREIDEL, LA; NACHMAN, MW; University of California, Berkeley; *mallory.ballinger@berkeley.edu*
Physiological, morphological, and behavioral plasticity to cold acclimation in temperate and tropical house mice
Understanding the contributions of phenotypic plasticity in adaptive evolution is a major goal in evolutionary biology. Since their recent introduction to the Americas, house mice (*Mus musculus domesticus*) have rapidly adapted to diverse habitats and climatic regimes. Mice inhabiting temperate regions have evolved larger body sizes, smaller ears, and shorter tails compared to mice in tropical regions. Phenotypic plasticity has likely played a major role in the house mouse's ability to rapidly adapt to these novel environments, yet, this hypothesis remains largely unexplored. To test this hypothesis, we reared wild-derived inbred populations of house mice collected from temperate (New York and Canada) and tropical (Brazil) environments in both a warm (21C°) and cold (4C°) environment. Following acclimation, we assessed the degree of plasticity in body size, tail length, nest-building, and mitochondrial metabolism. This design allows us to determine if the potential for adaptive plasticity differs with population and test the prediction that phenotypic plasticity following acclimation will mirror the evolved differences observed between temperate and tropical populations. Overall, our results reveal how plasticity evolves among populations adapted to different climates and shed light on how plasticity may have contributed to the house mouse's rapid colonization of such disparate environments.

P1-105 BALTZLEY, M; LATHAM-SCOTT, K; WANDERSCHEID, N*; RAMOS, M; BATENHORST, E; Western Oregon University; *nwanderschied14@mail.wou.edu*
The Effects of Larval Population Density and Social Interactions on Adult Fecundity in Drosophila melanogaster
Drosophila melanogaster is a model organism for studying sexual and mating behaviors. Previous research has shown that raising flies in isolation affects the development of the olfactory and visual systems. Because changes to the olfactory and visual systems could affect mating, we hypothesized that population density and social interactions as larvae will affect the fecundity of adult flies. To test this hypothesis, we raised larvae in a high density, a medium density, and in isolation. None of these population densities were food limiting. After eclosion, we set up nine different pairwise crosses of the adults (high-density female x high-density male, medium-density female x high-density male, etc.). We are recording the effect of larval density on eclosion patterns, body size, and fecundity. Our preliminary data suggest that females raised in a moderate density environment as larvae may be the most fecund. We will continue to run these crosses for a total of 10 replicates of each pairwise cross to gather more data for analysis. This research will contribute to the understanding of the effects of population density and social interactions on fruit fly behavior.

P2-202 BARBER, KS*; MIDDLEBROOKS, ML; BELL, SS; PIERCE, SK; University of South Florida, University of Tampa, University of South Florida & University of Maryland; *ksbarber@mail.usf.edu*
Feeding specificity of the sacoglossan sea slug Elysia papillosa
Elysia papillosa is a kleptoplastic, sacoglossan sea slug always found, associated with either of two species of the siphonaceous green alga, *Penicillus capitatus*, but also less frequently, with the co-occurring *P. lamourouxii*. In order to determine if *E. papillosa* was actually consuming either of the two algal species in the field, total DNA was extracted from individual slugs immediately upon collection from Sunset Beach, Tarpon Springs, FL and the gene sequence of *rbcL* (large subunit of ribulose bisphosphate carboxylase-a chloroplast geneomic gene) was determined by PCR. These PCR sequences were BLAST searched for matches to algal species *rbcL* sequences. The *rbcL* sequence from slugs collected off of *P. lamourouxii* matched (98-100% sequence identity) to *P. lamourouxii rbcL*. Similarly, *rbcL* in slugs collected with *P. capitatus* matched the *rbcL* sequence of *P. capitatus*. Therefore, *E. papillosa* were consuming the same algal species from which they were collected. In a laboratory feeding experiment, *E. papillosa* fed *P. lamourouxii* over three weeks grew significantly longer than those fed *P. capitatus*. These findings suggest that although feeding by *E. papillosa* on *P. lamourouxii* occurs in the field and results in larger slugs, *P. capitatus* is more attractive to slugs.

23-6 BARNETT, AA*; NAKAMURA, T; EXTAVOUR, CE; DeSales University, Harvard University; *austen.barnett@desales.edu*
Hox Genes Limit Germ Cell Formation in the Short Germ Insect Gryllus bimaculatus.
Hox genes are conserved transcription factor-encoding genes that specify the body regions of bilaterally symmetrical animals. In the cricket *Gryllus bimaculatus*, a member of the hemimetabolous insect group Orthoptera, the induction of a subset of mesodermal cells to form the primordial germ cells (PGCs) is restricted to the second through the fourth abdominal segments (A2-A4). In numerous insect species, the Hox genes *Sex-combs reduced (Scr)*, *Antennapedia (Antp)*, *Ultrabithorax (Ubx)* and abdominal-A *(abd-A)* jointly regulate the identities of middle and posterior body segments, suggesting that these genes may restrict PGC formation to specific abdominal segments in *Gryllus*. Here we show that all of these Hox genes, either individually or in segment-specific combinations, restrict PGC formation. Our data provides evidence for a segmental Hox code used to regulate the placement of PGC formation, reminiscent of the segmental Hox codes used in other arthropod groups to establish other aspects of segmental identity. These data also provide, to our knowledge, the first evidence for this ancient group of genes in restricting PGC development in any animal studied thus far.

P3-43 BARNS, BM*; MARTINI, J; RANKIN, B; DELAURENTIS, T; BAIER, D; Providence College, RI, Lincoln Memorial University, Harrogate, TN, Dana Farber Cancer Institute, Boston, MA, Providence College,RI; *bbarns@friars.providence.edu*

Mobility and stability of the turkey (Meleagris gallopavo) humeroulnar joint

The elbow joint in birds is typically considered to work as a simple hinge. However, some evidence from flying birds suggests greater complexity of movement. Additionally, the nature of the flapping wing likely places unusual demands on the elbow joint compared to other tetrapods. As the wing sweeps downward, the upward aerodynamic force would be expected to be greater on the distal wing, thereby generating a moment about the abduction/adduction axis of the elbow, perpendicular to its primary flexion/extension axis. We hypothesized specializations in the morphology and/or arrangement of the elbow ligaments to stabilize against this loading pattern, with particular focus on the ventral collateral ligament. In this study, we use X-ray Reconstruction of Moving Morphology (XROMM), to quantify the passive range of motion in turkey elbow by manipulating disarticulated wings. We also mapped ligaments onto digital models to explore their orientation during wing movement and explore which morphological features limit range of motion. We found ca. 90 degrees of flexion/extension, ca. 50 degrees of abduction/adduction movement, and ca. 40 degrees of long axis rotation at the humeroulnar joint (n = 4 wings). The range of abduction/adduction decreases with increasing extension of the elbow, suggesting that the ventral collateral ligament stabilizes the joint more effectively when the wing is fully extended as it is during downstroke of flapping flight. In order to achieve uniformity within interpretation of motion data for each trial, a standardized elbow joint coordinate system was established. This joint coordinate system used the inertial axes and key anatomical landmarks of the humerus, ulna, and radius, as the basis of its foundation.

P2-284 BARREIRA, SN*; BAXEVANIS, AD; NHGRI/NIH; *sofia.barreira@nih.gov*

Exploring the Role of Ribosomal Gene Repeats in the Context of Regeneration

Repetitive DNA has been implicated in chromatin organization, regulation of gene expression, genome replication, and the maintenance of genome integrity, but large repeats are often not found in reference genomes. Establishing the organization and distribution of repetitive DNA within a genome is crucial to fully understanding cellular function and for identifying new targets for therapeutic genome editing. Importantly, the process of regeneration depends on proper cell growth throughout the numerous cycles of cell division that, in turn, depends on the timely and flawless assembly of ribosomes. *Hydractinia*, a colonial marine cnidarian, is a proven model for the study of regeneration. Its stem cells are pluripotent and have homologs to human genes associated with the ability to self-renew and differentiate. We have identified a complete ribosomal gene consensus sequence in *Hydractinia*, and determined the genomic architecture of its rDNA repeats. A comprehensive protein domain structural analysis indicates that *Hydractinia*, does not possess the canonical UBF protein, a transcription factor that is known to bind to rDNA and is required for the recruitment of the Pol I transcription machinery during ribosome biogenesis. This opens the possibility that *Hydractinia*, might employ a different mechanism for regulating transcription of rDNA genes and nucleolar formation than that used by higher eukaryotes, perhaps providing important insight as to the regenerative capacity of this organism. This overall approach and comparison of these repeats and transcription factors between regenerative and non-regenerative organisms might reveal mechanisms that are primitive and shared among animals (or evolutionarily derived ones). This will help address key questions in regeneration and prompt the development of new clinical approaches to improve human health.

57-3 BARRETO CORONA, G*; DEBIASSE, M; RYAN, J; DAVIDSON, B; Swarthmore College, Whitney Marine Station, UFL; *gbarret1@swarthmore.edu*

The acquisition of self-sterility in a hermaphroditic tunicate

Tunicates, more specifically ascidians, offer an opportunity to investigate the mechanisms underlying adaptation. Two closely related ascidians, Corella inflata and Corella willmeriana allow us to specifically explore evolutionary changes in reproductive strategies. Ascidians are usually hermaphroditic and self-infertile. Strikingly, C. willmeriana appears to have conserved this ancestral trait, while C. inflata has acquired the ability to self-fertilize. There exists a known mechanism for self-sterility in Ciona Robusta that involves two pairs of hyper-variable allorecognition proteins - s-Themis and v-Themis that are associated with the sperm and vitelline coat respectively. Here we show that these genes are present in both Corellid transcriptomes but the acquisition of self-fertility in C. inflata is associated with paralog loss and potential degeneration. We performed alignments between the C. Robusta Themis genes and orthologs from the Correlid transcriptomes. We found that C. willmeriana may possess an extra v-Themis paralog whereas C. inflata may have lost one. Additionally, we found a substantially lower level of sequence conservation in the C. inflata orthologs. The apparent conservation of self-sterility genes in C. inflata suggests that the Themis genes are pleiotropic. We have begun long-read sequencing of Correlid genomic DNA to improve genome assembly and confirm our Themis ortholog predictions. We expect that our findings will provide insights into the evolution of hyper-variable genes in association with loss of traits involving allorecognition.

57-7 BARSHAD, G*; LEVI, T; ROTBLAT, B; MISHMAR, D; Ben Gurion University of the Negev, Beer-Sheva, Israel ; *barshad@post.bgu.ac.il*

Mitochondrial-nuclear transcriptional co-regulation: mechanism and phenotypes

The process of endosymbiosis transformed a former prokaryote, the mitochondrion, to play a central role in cellular metabolism. Such central role required co-regulation between nuclear DNA (nDNA) and mitochondrial DNA (mtDNA)-encoded factors. However, unlike the nDNA, vertebrate mtDNA genes are co-transcribed in polycistrones, thought to utilize a dedicated RNA polymerase and transcription factors. We hypothesized that since mtDNA- and nDNA-encoded gene products interact in the frame of the oxidative phosphorylation (OXPHOS) system, transcriptional co-regulation should occur. Indeed, by analyzing ~8500 RNA-seq experiments from 48 human tissues we showed a general positive mitonuclear gene expression correlation of OXPHOS genes, which was inversed only in sub-cortical brain regions. The best candidate to explain such mitonuclear co-regulation pattern was CEBP-betta, a transcription factor that both binds the mtDNA, and preferentially regulates nDNA-encoded OXPHOS genes. Here, we show that CEBPB silencing led to upregulation of both mtDNA- and nDNA-encoded OXPHOS genes, suggesting a mitonuclear transcriptional repressor role. We also show that such upregulation associates with increased OXPHOS function and decreased tumorigenesis. Since CEBPB has three translation products (LAP1, LAP2 and LIP), we asked which is responsible for the regulatory effect on mtDNA gene expression. Our results indicate that the shortest isoform, LIP, is the only mitochondrial-located isoform. We discuss CEBPB, which encodes both nuclear and mitochondrial transcription factors, as a key factor in coordinating mito-nuclear transcriptional regulation.

89-4 BARTS, N*; HENPITA, C; GREENWAY, R; ARNDT, S; SHAW, J; TOBLER, M; Kansas State University, Oklahoma State University, University of Cambridge, Oklahoma State University ; *barts2@ksu.edu*

Genetic, biochemical, and physiological adaptation in fish inhabiting sulfide-rich environments

A fundamental goal of evolutionary biology is to understand the relationship between genotype and phenotype, providing insights into physiological, biochemical, and genetic mechanisms underlying adaptation. Exploring how changes across levels of biological organization ultimately lead to phenotypes observed in nature benefits from studying organisms that experience environmental conditions with predictable consequences on physiological function. Hydrogen sulfide (H2S) is a natural toxicant that inhibits aerobic ATP production by binding to cytochrome c oxidase (COX) in the mitochondrial respiratory chain and is regulated by the sulfide:quinone oxidoreductase (SQR) pathway. We used multiple population pairs of *Poecilia mexicana* in habiting sulfidic and non-sulfidic habitats to show that genes encoding toxicity targets and detoxification pathways are under positive selection and differentially expressed. In addition, we explored the influence of hydrogen sulfide on enzymatic function of COX, other mitochondrial respiratory complexes, and SQR, and how changes in the functionality of these enzymes influence mitochondrial physiology. Specifically, we quantified variation in enzymatic activity in the mitochondrial complexes and key detoxification genes and relate changes in enzymatic function to mitochondrial performance in the presence and absence of H2S. Preliminary results provide evidence for selection on Complex I and IV in sulfide-tolerant populations of *P. mexicana*, that concentrations of H2S within mitochondria increase more quickly in sulfide-intolerant populations exposed to H2S, and that mitochondrial performance deteriorates more quickly in sulfide-intolerant populations exposed to H2S.

105-1 BASU, CK*; RICHARDS, CT; Royal Veterinary College; *cbasu@rvc.ac.uk*

Modelling the effect of long axis rotation on hindlimb moment arms in the red-legged running frog Kassina maculata

Frogs exhibit a varied suite of locomotor behaviours. Intrinsic to this repertoire is the property of selected joints to rotate with three degrees of freedom. In the hip joint, this is reflected by the complex musculature surrounding the acetabulum. Hip muscles acting in the flexion-extension and adduction-abduction planes are well-known contributors to locomotor behaviours, such as jumping. Long axis rotation (LAR) of the femur is less frequently studied, in part due to the challenges associated with measuring LAR in-vivo. We have performed a kinematic simulation to assess the effect of LAR on muscle function during jumping, using empirical data gathered from *Kassina maculata* (the red-legged running frog) and a musculoskeletal model implemented in the physics engine MuJoCo. We imposed a ± 20° LAR onto the femur of *K. maculata* during a static point in the early, mid and late stance phase of a jump. The three-dimensional moment arms of hip muscles were measured across this range of LAR, and are presented in the context of anatomical reference planes. We found that the imposition of LAR switched the function of the obturator externus, gluteus maximus, iliacus externus, and iliolumbaris muscles. These muscles are generally of low power, with a mean PCSA of 2.7 mm^2 (compared with the more powerful knee extensor muscles), so the functional significance of moment arm sensitivity to LAR requires further investigation. We speculate that these muscles may shift their functions if the degree of LAR changes during locomotor behaviours. Because of their low force capacity, we expect them to play an important role in modulating power produced by larger muscles. We will test our model's predictions by measuring LAR in jumping frogs using xray reconstruction of moving morphology (XROMM).

S12-6 BAUER, AM; Villanova University; *aaron.bauer@villanova.edu*

Gecko Adhesion in Space and Time: A Phylogenetic Perspective on the Scansorial Success Story

An evolutionary perspective on gecko adhesion was previously hampered by a lack of an explicit phylogeny for the group and of robust comparative methods to study trait evolution, an underappreciation for the taxonomic and structural diversity of geckos, and a dearth of fossil evidence bearing directly on the origin of the scansorial apparatus. With a multigene dataset as the basis for a comprehensive gekkotan phylogeny and the recognition that geckos comprise perhaps the most species-rich group of squamates, model-based methods have recently been employed to estimate the number of unique derivations of the adhesive system and its role in lineage diversification. However, a lack of resolution in parts of the tree and differences in assumptions and analytical approaches has led to differing conclusions. Evidence points to a single basal origin of the spinulate Oberhäutchen, which is a necessary precursor for the subsequent elaboration of a functional adhesive mechanism in geckos, but multiple gains and losses of the fully manifested scansors. Both time-calibrated trees and recently discovered amber fossils that preserve gecko toepads suggest that a fully-functional adhesive apparatus was not only present, but represented by diverse architectures by the mid-Cretaceous. Genomic approaches hold the promise of both further resolving gekkotan relationships and identifying the underpinnings of structural elaborations of gecko keratins. Further characterization and phylogenetically-informed analyses of the other components of the adhesive system (muscles, tendons, blood sinuses, etc.) will also permit a more comprehensive reconstruction of the evolutionary pathway(s) by which geckos have achieved their structural and taxonomic diversity.

S4-9 BAUM, D*; KNöTEL, D; DEAN, M N; Zuse Institute Berlin (ZIB), Max Planck Institute of Colloids and Interfaces, Germany; *baum@zib.de*

Shape models for image segmentation and geometric analysis of biological structures

When we look at images and search for certain objects in them, like cats or trees, our brain makes use of mental images that we have of those objects. The better we know the objects, the clearer our mental images, the easier it is to spot the objects. Mental representations are one of the reasons our visual system is often better at image processing tasks than even very advanced image analysis tools. Here, we will discuss approaches for teaching such representations to computers to facilitate automated 3D image analysis of very large numbers of objects from tomographic (microCT, ET) data, drawing on examples from projects on quantifying subcellular structures, tessellated cartilage, corals and others. One approach uses rather general information —"the object is roundish" or "flat"— which is then incorporated into the image analysis process. The second approach describes the object more explicitly, for example, by using a geometric shape model derived from several objects of the same kind and represented by the mean shape of these objects together with their possible variations. This approach is particularly suitable when the object's shape is rather conserved, which is usually true for anatomical structures. A third approach, less addressed here, is to use deep neural networks to identify shapes. This can give remarkable results but requires large amounts of training data. We will also present how shape models used in approach 2 can be applied to study how structures and materials change in evolution. Of particular interest are shape models that are generative in the sense that they can generate new objects rather than only reproducing input data. One utility of this could be the reconstruction of fossil data that is only partially preserved.

P2-217 BAUMAN, TJ*; STAAB, KL; McDaniel College;
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Cartilage-like Connective Tissues in the Hyoid Region of Cypriniform Fishes

Suction feeding in cypriniform fishes may not fit other hydrodynamic models and the hyoid region likely plays a crucial role in generating intraoral subambient pressure to generate flow and pull food into the mouth. In unrelated acanthomorph fishes the hypaxial muscles were shown to generate power behind suction feeding and because those forces are transmitted through the hyoid, it has become of more interest. In cypriniforms the hyoid region may be of more functional relevance because some species are lacking the characteristic head lift movement in suction-feeding acanthomorphs. The hyoid apparatus includes multiple bones, joints, and linkages composed of diverse connective tissues that likely play differing functional roles. To characterize the composition of the tissues within the hyoid region in cypriniforms we examined three species: goldfish, *Carassius auratus*, zebrafish, *Danio rerio*, and blacknose dace, *Rhinichthys atratulus*. Based on histological stains of the hyoid apparatus we found varying types of cartilage-like connective tissues in functionally relevant structures. For instance, the ceratohyal of all species contained a medio-laterally oriented region of densely packed cells that stained consistently high for mucopolysaccharides, but this cartilage-like element did not fill the entire bone. The medial edges of the hypohyals are covered in a tissue that is distinct from the sternohyoideous tendon in between. This articular tissue is also comprised of densely packed cells with less extracellular matrix and lower affinity for the mucopolysaccharide stain. Throughout the entire hyoid region in all species, the hyoid elements were composites, staining for a range of mineralized and cartilage-like materials. These findings are important because they can inform our understanding how cypriniforms suction feed.

47-5 BAZARINI, SN*; CROOK, RJ; San Francisco State Univ.;
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Effects of Ethinyl Estradiol on Injury-Induced Plasticity in Euprymna scolopes

It is widely accepted that estrogens affect the development of chronic pain, but the mechanism is not well understood. Pain studies involving mammals are complicated by estrogen's role in cyclical fertility, and there is little research on animal models that lack estrogen cycles. The cephalopod *Euprymna scolopes* is a promising model for such studies. Its nervous system is large and complex, and cephalopods express estrogen receptors in brain areas involved in cognition, long-term memory and sensory processing. *E. scolopes* demonstrates both short- and long-term sensitization after injury, and as a coastal marine organism, is vulnerable to increasing levels of estrogenic pollutants in surface waters. To determine the effects of estrogen exposure coupled with injury on the nervous system of the squid, I will expose groups to either no, chronic, or acute doses of ethinyl estradiol (EE2) in tank water and compare neuroanatomy, behavior and neural excitability among the treatments. Half the squid in each group will receive a tissue injury at 14 days post hatching. The chronically exposed squid will be reared in water containing a low dose of EE2 throughout life, replicating the effect of chronic environmental exposures. The acutely exposed group will receive a single higher pulse of EE2 added to water prior to injury, mimicking the interaction of an estrogen peak co-incident with inflammation. I hypothesize that estrogen exposure heightens behavioral and neural sensitization after injury. However, preliminary data suggests that estrogen-exposed squid show reduced responses to injury. This work will increase our understanding of conserved mechanisms of estrogen/injury interactions and will improve knowledge of eco-systems effects of environmental estrogens.

51-4 BEATTY, AE*; SCHWARTZ, TS; Auburn University;
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Quantifying gene expression of top regulators of the Insulin and Insulin-like Signaling Network in the brown anole across tissues and developmental stages.

The Insulin and Insulin-like Signaling (IIS) network regulates cellular processes including pre- and post-natal growth, cellular development, wound healing, reproduction, and longevity. Recent work at the sequence level has demonstrated that the IIS network has been rapidly evolving in reptiles relative to mammals, raising questions about how the transcriptional regulation of the IIS network may have also evolved. Here we compare the expression of the top regulators of the IIS network —IGF hormones (IGF1, IGF2), IGF binding proteins (IGFBP1, IGFBP2, IGFBP3, IGFBP4, IGFBP5) and the IGF1 receptor (IGF1R) — in a lizard to what is known in rodents. IGFBPs regulate the circulation of IGF hormones, facilitating tissue-specific binding of these hormones to their receptors, activating the network. Despite their importance on the physiology of vertebrates, the specific functions of each IGFBP and each IGF hormone is relatively unknown in reptiles. To address this, we first assay the presence of expression of IGFBPs, the IGF hormones, and IGF1R across tissues and ages (embryo to adulthood). In adults, both IGF1 and IGF2 are expressed in all tissues, but the ratio of IGF1 to IGF2 changes significantly with age. IGFBP3-IGFBP5 are expressed ubiquitously across tissue in adults, but IGFBP2 is not expressed in the heart and IGFBP1 is only expressed in the liver. Second, we develop and employ a multiplex qPCR assay for absolute quantification of IGF1, IGF2, and the IGF1R gene expression in liver, brain, skeletal muscle, and gonadal tissue at 7 ages, emphasizing early life stages. We will contrast these results to patterns found in mammals. The data collected in this study is essential for future studies of the IIS network in reptiles, as well as understanding the relative roles of IGF1 and IGF2 in development of the *Anolis* lizard.

51-5 BEBUS, SE*; JONES, BC; ANDERSON, RC; Univ of Memphis, TN, Florida State Univ, Tallahassee, Florida Atlantic Univ, Davie; *sarabebus@gmail.com*

Development of the Corticosterone Stress Response Among Passerine Nestlings

When homeostasis is disrupted, vertebrates respond by activating the hypothalamic-pituitary-adrenal (HPA) axis, which leads to the release of glucocorticoids (GC). GCs, including corticosterone (CORT, the main avian GC), are steroid hormones that serve a crucial role in the response to and recovery from stress. The development of the CORT response can depend on the life history strategy of a species. For instance, the developmental hypothesis predicts that altricial young have a dampened CORT response, because nest-bound young likely do not benefit from the escape and post-escape actions of CORT. However, there is a lack of comparative studies that assess possible variation in CORT response among altricial species with different life history strategies. We compared the development of the CORT response in a brood parasite passerine, the brown-headed cowbird (*Molothrus ater*), and five non-parasitic passerines to determine if the magnitude and development of the stress response differs. We quantified baseline and stress-induced CORT levels from blood samples collected throughout the nestling period. The magnitude and development of the stress response of cowbirds was similar to those of eastern phoebes (*Sayornis phoebe*), hooded warblers (*Setophaga citrina*), red-winged blackbirds (*Agelaius phoeniceus*), and song sparrows (*Melospiza melodia*). Surprisingly, the CORT response of gray catbirds (*Dumetella carolinensis*) was significantly lower throughout the nestling phase. Overall, our results support previous findings that passerine nestlings have a dampened CORT response that develops with age. We did not find evidence that the development of the HPA axis in a brood parasite species differed from most non-parasitic passerines. However, the especially low CORT responsiveness of catbird nestlings raises new questions about their development and possible life history strategies.

S2-5 BECKER, DJ*; ARGIBAY, HG; BOTTO, G; ESCALERA-ZAMUDIO, M; GREENWOOD, AD; ROJAS-ANAYA, E; LAVERGNE, A; DE THOISY, B; CZIRJáK, GÁ; PLOWRIGHT, RK; ALTIZER, S; STREICKER, DG; Montana State University, Universidad de Buenos Aires, University of Oxford, Leibniz Institute for Zoo and Wildlife Research, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Institut Pasteur de la Guyane, University of Georgia, University of Glasgow; *daniel.becker3@montana.edu*
Quantifying and interpreting spatial autocorrelation in leukocyte profiles in a widespread Neotropical bat species
Why are some populations more or less susceptible to disease? Populations may experience greater stress and impaired immunity at their geographic range limits and in areas subject to abiotic or biotic stressors. Identifying environmental correlates of immunity could help to anticipate disease risks, but achieving this goal has been limited by a lack of studies measuring immunity across the range of broadly distributed species. We present a case study for landscape immunology where we analyze leukocyte profiles from 39 colonies of vampire bats (*Desmodus rotundus*) throughout the Neotropics. Leukocyte profiles showed high spatial variation, with proportions of neutrophils and lymphocytes varying up to six-fold. Leukocyte profiles were spatially autocorrelated at small and vary large distances, suggesting that local environment and biogeography can both influence constitutive immunity. Vampire bats from relatively colder, drier, and more seasonal habitats (characteristic of the northern and southern range limits) had relatively more neutrophils, monocytes, and basophils than bats sampled at core and tropical regions. Our findings suggest colonies at the edge of their range may experience stressful conditions that predict investment in cellular innate immunity and inflammation response. We outline how applying a similar landscape perspective to immunology in other species could help predict emerging disease risks.

S2-1 BECKER, DJ*; SCHOENLE, LA; DOWNS, CJ; MARTIN, LB; Montana State University, Hamilton College, University of South Florida; *daniel.becker3@montana.edu*
The scale of sickness: how immune variation across space and species affects infectious disease dynamics
Biology, relative to physics and much of chemistry, lacks strict organizing principles. Whereas physicists can predict with exquisite accuracy how far a ball will fly when thrown, biologists lack the mathematical and conceptual framework to make precise predictions. Conversely, biologists have become extremely adept at collecting massive and often complex datasets, even from a variety of non-model organisms living in diverse habitats. Our goal for this symposium is to lay a foundation for describing the general principles that explain the relationships between variation in immune defenses and the ecology and evolution of infectious diseases. This goal is derived from the perplexing observation that hosts and parasites vary so much their propensities to resist and infect each other, respectively. What are the principles that determine whether a host is infected by one or many parasites, whether a single or many hosts transmits parasites to other susceptibles, and whether a parasite kills or keeps its host alive upon infection? These questions are fundamental, yet we have only recently taken the multidisciplinary and multi-scale approach necessary to develop principles for host-parasite interactions, as some recent work shows. In this symposium, we hope to challenge participants and attendees to conceive scientific approaches that connect individual-, landscape-, or species-level variation in immune defense to their eco-evolutionary and epidemiological outcomes.

28-4 BEDGOOD, SA*; BRACKEN, MES; Univ. of California, Irvine; *sbedgood@uci.edu*
Sea Anemone Diet Affects Algal Symbiont Photochemical Efficiency
The stability of nutrient exchange in a mutualistic symbiosis is highly dependent on the availability of resources to both partners. Thus, depending on resource availability, some conditions could be favorable for symbiosis while others could inhibit symbiosis or even result in a break-down in the interaction. Symbiotic sea anemones on California rocky shores obtain nitrogen and some carbon from prey that they capture. Some of the nitrogen from prey is translocated to algal symbionts living within the sea anemone tissue. Unlike some tropical symbioses with algal symbionts, nitrogen is plentiful and is frequently excreted as waste if it is not used by the symbionts. In exchange, the algal symbionts translocate fixed carbon to their host anemone. Algal symbionts are therefore highly advantageous when prey is scarce but may not be as useful when prey, and therefore dietary carbon, is plentiful. To test this hypothesis, we designed an in situ experiment where the diet of two closely related sea anemones, *Anthopleura sola* and *A. xanthogrammica*, was manipulated by either adding or removing prey daily for three weeks. Algal symbiont condition was measured using a pulse-amplitude modulated fluorometer and by taking tissue samples to quantify symbiont density and chlorophyll a concentrations. Even though both species interact with the same symbiont genotype, they responded to the treatments differently. Symbionts within *A. xanthogrammica* increased their photochemical efficiency (F_v/F_m) when prey were supplemented as compared to a control, whereas symbionts within *A. sola* did not change photochemical efficiency in any treatment. This suggests that *A. xanthogrammica* may be able to take advantage of an increase in prey availability and pass on benefits to its symbionts, whereas *A. sola* cannot.

101-4 BEDWELL, H*; DIXON, G; BAY, L; MATZ, M; The University of Texas at Austin, Australian Institute of Marine Science; *hbedwell@utexas.edu*
Mitochondrial variation as a source of adaptive genetic variation to heat stress in corals
Reef-building corals are under strong selection for higher thermal tolerance as increasingly frequent thermal stress events are causing worldwide die-offs. Until recently, the mitochondrial (mt) genome has been overlooked as a source of adaptive genetic variation. Current studies suggest mt genomes can maintain non-neutral polymorphisms under strong selection, and these polymorphisms can be linked to variation in host fitness. Most of the previous literature has focused on thermal tolerance associated with the coral's symbiotic algae. However, a recent study revealed *Acropora millepora* larval thermal tolerance depends on maternal background, suggesting mt variation might play an important role in coral thermal tolerance. Four adult colonies from two locations in the Great Barrier Reef (GBR) were cross-fertilized, and their larvae were scored for thermal tolerance. Maternal effects accounted for 66% of the total variation (87%) in thermal tolerance. In addition, larvae of parents from the warmer location had significantly higher thermal tolerance than larvae of parents from the cooler location. Analysis of gene expression revealed heat-tolerant larvae up-regulate nuclear-encoded mt membrane components, along with oxidoreductase activity, which was suggested to contribute to the high maternal effect. Beyond that experiment, this potentially key aspect of coral thermal tolerance remains unexplored. Currently, there are two known mitochondrial haplotypes in *A. millepora*, which are both found at high frequencies in populations spanning the GBR. Experiments are being conducted to determine whether haplotype frequencies correspond to local thermal regimes and how mt variation impacts adult thermal tolerance.

92-8 BEHBAHANI, AH*; MELIS, JM; DICKSON, WB; DICKINSON, MH; Caltech; *amirhb@caltech.edu*

Fruit flies must overcome inertial torques to modulate wing pitch

Flying fruit flies must control all six degrees of body motion via subtle changes in wing kinematics. Several studies indicate that changes in wing pitch, which largely determine the angle of attack, are particularly important for controlling body yaw. In addition, prior research suggests that flies might regulate wing pitch via a passive mechanism in which they only adjust the torsional stiffness about the long axis of the wing. During each stroke, the wing then rotates under inertial and aerodynamic torque to adopt the correct angle of attack. However, this model does not preclude the possibility that flies also actively rotate their wings through the action of the wing hinge and steering muscles. The goal of our study was to develop a general model of wing rotation to gain insight into the relative contributions of active and passive mechanisms. Using realistic morphometric and kinematic values from the literature, we derived an equation of motion for the pitch axis of the wing. We solved for the time history of wing pitch and compared it to the actual pattern generated by a fly, using kinematics collected from free flight sequences. We performed a sensitivity analysis on various parameters and found that the solution depends quite strongly on the location of the center of pressure, the mass distribution of the wing, and the level of smoothing applied to the positional data. For data from free flight, in which the mid-stroke angle of attack is relatively constant at ~45˚, we found that the center of pressure is quite close to the axis of rotation and the aerodynamic torque is smaller than inertial torque. Based on the relationship between the required torque and the wing pitch angle, our results suggest that flies must exert some active control over wing pitch to achieve their remarkable aerial agility.

P1-12 BELANGER, RM*; GRABOWSKI, GM; JOSHI, GS; TUTTLE, JE; University of Detroit Mercy, ; *belangra@udmercy.edu*

Exploring the pathophysiology of diabetes: Development of an inquiry-based laboratory module

The NSF calls on scientific educators to actively involve students in their learning process, rather than make them passive learners. Histotechnology is a commonly used tool in medical research, pathological testing, and pharmaceutical development. We developed a three-week, inquiry-based laboratory module that equips our students with the knowledge of tissue sampling, processing and imaging so that they are ready for careers in the biomedical sciences. We induced diabetes in rats by injecting them with streptozotocin while control rats were injected with buffer solution. Students compared pre- and post-injection weights following one week of treatment, as well as final blood samples for glucose and insulin concentrations using an ELISA. Additionally, pancreatic tissue was collected, fixed, and paraffin embedded. Students sectioned and stained prepared slides using a hematoxylin/phloxine protocol. The number of islet beta cells were compared between control and treated rats. Blood glucose measurements demonstrated that treated rats had significantly higher blood glucose levels and lower beta cells numbers, while the ELISA tests indicated that treated rats had significantly lower blood insulin concentrations. Following this three-week laboratory module, students scored higher on competency tests and presented an individual report with images and quantitative data analyses that included insulin concentrations, blood glucose levels, and histological images of pancreatic islets, in addition to beta cell quantification. In summary, students who completed this three-week laboratory module were able to experimentally investigate and link the clinical symptoms of type 1 diabetes which include weight loss, increased blood glucose and decreased insulin levels and relate them to the underlying physiological cause, the destruction of pancreatic beta cells.

P2-277 BELFIORE, NM*; NOORDSIJ, LC; University of Tampa; *nbelfiore@ut.edu*

Comparative Genomics of Four Mustelid Species

North American river otters (*Lontra canadensis*) have the second largest latitudinal range of any otter species, from boreal Canada to southern Mexico. This broad range corresponds to broad dietary, physiological, and behavioral patterns. By contrast, it follows a restricted mating period, and a narrower birthing period. This species undergoes delayed implantation, in which the fertilized embryo sits dormant inside the uterus of the mother until approximately 40 days before the optimal birth season is anticipated, when it implants and begins to gestate. This pattern fits the constraints of living in the far north, with a very short warm season, when it would be critically important to give birth and raise nurslings only during optimal weather. It is particularly interesting that this pattern of delayed implantation is not found in other closely related otter species whose ranges are more extensive than that of the North American river otter, such as the Eurasian otter (*Lutra lutra*). In this preliminary study, we obtained genomic libraries generated by paired-end IlluminaTM sequencing at approximately 30X coverage from the North American river otter, the Eurasian otter, the African clawless otter (*Aonyx capensis*), and the American mink (*Neovison vison*). The African clawless otter does not undergo delayed implantation, while the mink, a member of the same family, but separate subfamily does undergo a limited implantation delay. We generate reference-guided assemblies of these species to compare the genomic content and structure from 69M sequences from the North American river otter, 102M sequences from the African small clawed otter, 70M sequences from the Eurasian otter, and 165M sequences from the American mink. The domesticated form of the European polecat (*Mustela putorius*), or the ferret, is used as a reference genome.

16-5 BELNAP, S.C.*; LICKLITER, R.; Florida International University, Miami; *sbelnap@fiu.edu*

Incubation Temperature Influences Fall Frequency In Bobwhite Quail Neonates

Maternal influences on offspring occur not only during egg formation, but also during prenatal development in both birds and mammals. During incubation, avian hens provide key elements essential for normal embryonic development, including temperature regulation. Previous work indicates developing avian embryos are sensitive to small fluctuations in temperature and respond to fever-like temperatures with increased prenatal activity. Here, we examined the influence of maternally regulated prenatal temperature on postnatal motor coordination in bobwhite quail. Starting on embryonic day 5 (of 23), randomly assigned quail embryos experienced 4 days of low (36.9°C), normal/control (37.5°C), or high (38.1°C) temperature. Growth parameters of weight and tarsometatarsus bone length were collected prior to testing. Motor coordination was measured at 24 hours after hatching during a video recorded ambulation task. Videos were analyzed for gait patterns, including fall frequency, stride length, and base of support (BOS). Results revealed no differences in growth parameters between temperature conditions. However, hatchlings in the low and high temperature conditions fell significantly more often compared to controls. Further, hatchlings in the low and high conditions showed more variability in their BOS, and low condition hatchlings showed more variability in their stride length, suggesting a decline in motor control. These findings suggest optimal prenatal temperature promotes the development of a more coordinated motor system. The processes contributing to this link are currently under investigation.
[NSF grant BCS 1525371]

24-7 BELOTT, CJ*; MENZE, MA; Univ. of Louisville, Kentucky; *cjbelo01@louisville.edu*

Membraneless Organelles in Desiccation Tolerance: A New Phase in Physiology

Our understanding of protein liquid-liquid phase separation (LLPS; ‘membraneless organelles') and its importance in a wide range of biological phenomena is rapidly growing. Unexpectedly, protein LLPS may also play a role in the desiccation- and osmotic-stress tolerance of encysted *Artemia franciscana* (brine shrimp) embryos. *Afr*LEA6 is an intrinsically disordered protein in *Artemia* that shares homology with seed maturation proteins (SMPs) found in some plant seeds. SMPs have been linked to the duration in which a seed remains viable in the dried state. Therefore, it was hypothesized that *Afr*LEA6 may play a role in sustained tolerance to water stress. This hypothesis was tested by ectopically expressing *Afr*LEA6 in desiccation-sensitive *Drosophila melanogaster* (Kc167) cells and exposing these cells to water stress. *Afr*LEA6 was found to increase both desiccation and osmotic-stress tolerance of Kc167 cells. Furthermore, confocal microscopy was used to image LLPS of *Afr*LEA6 *in vivo*. Staining cells with Nile Red, a lipophilic dye, suggested that *Afr*LEA6 causes the cytosol to interact with Nile Red like an aqueous-organic cosolvent mixture. Altered solvent properties may decrease the thermodynamic stability of unfolded proteins and reduce native protein conformational mobility yielding cytosolic wide stabilization of native proteins. Altogether, these data support the hypothesis that *Afr*LEA6 plays a role during water loss and indicates that *Afr*LEA6 significantly impacts the physicochemical properties of the cytosol. (Supported by NSF *IOS*-1659970.)

32-4 BEMIS, K.E.*; HILTON, E.J.; Virginia Institute of Marine Science; *kebemis@vims.edu*

Tooth development and replacement in Longnose Lancetfish, Alepisaurus ferox (Teleostei: Aulopiformes: Alepisauridae)

The Longnose Lancetfish, *Alepisaurus ferox*, feeds on hyperiid amphipods, pelagic polychaete worms, mesopelagic fishes, and cephalopods using a heterodont dentition that includes exceptionally large, fangs. We used dry skeletons, histology, and microcomputed tomography (CT) scanning to study a series of 40 specimens of *A. ferox* from the western North Atlantic and North Pacific oceans to describe its dentition and tooth replacement. The smallest teeth in the oral jaws are found on the premaxilla. These teeth are conical in shape and uniform along the length of the premaxilla, whereas the other bones of the oral jaws have heterodont dentitions. The palatine and dentary both have elongate, laterally compressed fangs and a series of sharp triangular teeth that are slightly recurved. In addition, the dentary also has anterior symphysial teeth, tall conical teeth, and a series of small, laterally compressed teeth. Despite differences in sizes and shapes of teeth all are replaced extraosseously. Teeth develop horizontally in the oral epithelium on the lingual surface of dentigerous bones. The developing teeth rotate into place and subsequently ankylose to the bone. Functional teeth ankylose to the bone through a ring of ossification that forms at the base of each tooth on the lingual side of the bone. This is the first study to document extraosseous horizontal replacement of large fangs in teleosts, although large fangs are rotated extraosseously in snakes. We compare this mode of tooth replacement to intraosseous horizontal fang rotation found in the scombroid *Trichiurus lepturus* that has convergently evolved this mechanism to accommodate the presence of large fangs.

P1-247 BENEDICT, C*; LAROCHE, R; TITUS, B; GUSMãO, L; MEYER, C; ABDULLAH, ML; BARTHOLOMEW , A; DALY, M; REIMER , JD; YANAGI , K; RODRíGUEZ , E; Auburn University, University of Houston, American Museum of Natural History, American Museum of Natural History, National Museum of Natural History, University of Science and Technology, American University of Sharjah, Ohio State University, University of the Ryukyus, Natural History Museum and Institute-Chiba; *charlottebenedict3@gmail.com*

Phylogenetic relationships among the clownfish-hosting sea anemones reveals at least four independent origins of the symbiosis

The systematics and evolution of the ~30 described species of clownfishes have been heavily studied, the clownfish-hosting sea anemones are poorly represented in phylogenetic studies of sea anemones. Currently there are 10 morphologically described clownfish-hosting sea anemones within five genera. These include Entacmaea, Heteractis, Stichodactyla, Cryptodendrum, and Macrodactyla. Although the current anemone taxonomy suggests multiple independent evolutionary origins of symbiosis with clownfishes, no anemone phylogenetic dataset has included representatives of more than 5 taxa in a single analysis. Here we use broad biogeographic sampling and newly generated mtDNA and nuDNA datasets to investigate the phylogenetic placement of 9/10 clownfish hosts within Actinioidea. We test the hypothesis derived from the current taxonomy that symbiosis with fishes evolved independently across Actinioidea, and we also test the monophyly of each anemone genera. Our phylogenetic reconstruction confirms that symbiosis with fishes evolved independently across the Actinioidea. Our data suggest at least four independent evolutionary origins of symbiosis with clownfishes. We recover the genus Heteractis as paraphyletic while confirming the monophyly of Stichodactyla. While our dataset represents the most extensive investigation into the clownfish hosting sea anemones, many family-level relationships and below are poorly supported. Genomic markers with greater resolution will provide greater phylogenetic insight into anemones within the Actinioidea and the lineages symbiotic with clownfishes.

P1-219 BENESH, KC*; MAHON, AR; Central Michigan University; *benes1kc@cmich.edu*

Impact of Reduced Genomic Datasets on Population Genetic Analysis of SNP Data from the Invasive Grass Carp

Advances in sequencing technology have allowed for greater amounts of genomic data to be obtained from organisms at an increasingly more feasible cost. However, the amount of processing power and time required for analysis of this information has simultaneously increased. While utilization of whole genomes from even a limited number of individual for population studies is not yet feasible, reduced representation genomic scans are becoming more and more common. In this study, the impact of reduction schemes on population genomic analyses of a non-modal organism, grass carp (*Ctenopharyngodon idella*), is investigated. A high coverage single nucleotide polymorphism (SNP) dataset was generated using 2b-RAD sequencing. Genome scans were generated from a small number (n=23) of grass carp collected from Lake Erie. Reads were then used to construct a *de novo* reference sequence, which subsequently identified SNPs throughout the genome. To determine the population structure of grass carp, analyses including a Discriminant Analysis of Principal Components (DAPC) were performed. To investigate the effect that sequence read number has on determining population structure, the number of reads was reduced in a stepwise fashion and re-analyzed. A single putative population was resolved, and this was corroborated in all dataset reductions that we analyzed. Often specimen quality and/or quantity can limit the amount of genetic material available for analysis, such as in conservation studies or those involving invasive species that are expanding into new habitats. Understanding how reductions in datasets can impact the accuracy of inferences made about populations provides insight into the mechanics and statistics of reduction schemes on large genomic datasets.

102-1 BENOWITZ-FREDERICKS, ZM*; CAINE, PB; MALISCH, JL; EDWARDS, KM; FARMER, JL; HAUSSMANN, MF; HATCH, SA; Bucknell Univ., St. Mary's of Maryland, Inst. Seabird Research & Cons.; *zmbf001@Bucknell.edu*

Acute Administration of Exogenous Corticosterone in Seabird Chicks Rapidly Mobilizes Lipids but not Glucose

In developing birds, costs of elevated glucocorticoids have been repeatedly demonstrated while benefits - reallocation of endogenous resources - are often assumed. Although mobilization of glucose in response to elevated glucocorticoids occurs in mammals, some studies suggest that in birds, lipid rather than glucose mobilization may be the primary resource reallocation pathway. However, most of the evidence about relationships between glucocorticoids and glucose in birds is either conducted in captivity or correlational, based on concurrent increases in corticosterone (cort) and glucose during capture-and-handling protocols. We tested the hypothesis that in free-living birds, cort has a larger effect on the acute mobilization of lipid-based energy substrates than on glucose. We administered a single oral dose of cort in oil to black-legged kittiwake (*Rissa tridactyla*) chicks; total handling time averaged 20 sec. We collected blood 15, 30, or 60 min after cort administration and compared circulating glucose, triglycerides, and cholesterol in cort-treated chicks to those in oil-only controls and unhandled controls. At 30 min, both groups of handled chicks had elevated glucose compared to unhandled controls, but cort and oil treatments did not differ.. Triglycerides were not responsive to treatments, however, cholesterol was elevated in cort chicks 15 min after administration, suggesting non-genomic effects of corticosterone on cholesterol mobilization. Disentangling the roles of catecholamines and glucocorticoids will require additional experimental manipulations and attention to very short time scales.

P3-106 BENRABAA, S.A*; MYKLES, D.L; Colorado state univeristy; *saabmora@rams.colostate.edu*

Effect of blocking TGFβ/activin signaling on hemolymph ecdysteroid titers and expression of Halloween and ecdysteroid-responsive genes in the molting gland (Y-organ) of the blackback land crab, Gecarcinus lateralis

Molting is controlled by ecdysteroids synthesized and secreted by the molting gland, or Y-organ (YO). Halloween genes encode enzymes that catalyze the synthesis of ecdysteroid hormones. Ecdysteroid receptor *(EcR/RXR)* binds active molting hormone, which induces serial activation of ecdysteroid-responsive genes. During premolt, TGFβ/activin signaling mediates the transition of the YO from the activated to the committed state, as SB431542 blocks this transition. *G. lateralis* were eyestalk-ablated to induce molting and injected with vehicle (DMSO) or SB431542 at Day 0. In controls, ESA increased hemolymph ecdysteroid titers at 3, 7 and 14 days post-ESA. There were significant increases in the mRNA levels of *Gl-Nvd* at 7 and 14 days post-ESA and other Halloween genes (*Gl-Spo*, *Gl-Phm*, *Gl-Dib*,*Gl-Sad*), as well as *Gl-CYP18a1*, *Gl-ALAS*, *Gl-NADK*, *Gl-BR-C*, *Gl-EcR*, and *Gl-RXR*, at 14 days post-ESA. SB431542 reduced hemolymph ecdysteroid titers at 7 and 14 days post-ESA compared to control animals, but titers were no different from controls at 1, 3, and 5 days post-ESA, indicating that SB431542 had no effect on YO activation. SB431542 blocked the increases in RNA levels of *Gl-Nvd*, *Gl-Spo*, *Gl-Phm*,*Gl-Dib*,*Gl-Sad*, *Gl-CYP18a1*,*Gl-ALAS*, *Gl-NADK*,*Gl-BR-C*,*Gl-EcR*,and *Gl-RXR* by ESA. SB431542 had no effect on mRNA levels of the ecdysteroid-responsive genes *Gl-HR3*, *Gl-HR4*,*Gl-E74*,*Gl-E75* and *Gl-FTZ-F1*. These data suggest that an activin-like TGFβ factor stimulates YO ecdysteroidogenesis in the committed YO by up-regulating Halloween genes and the *Gl-BR-C* ecdysteroid-responsive gene. Supported by NSF (IOS-1257732).

15-2 BENSON, BE*; CASTILLO, KD; BAUMANN, JH; AICHELMAN, HE; STANIZZI, DA; DAVIES, SW; Boston University, University of North Carolina at Chapel Hill; *bebenson@bu.edu*

Increased Diel Thermal Variability Promotes Growth and Symbiosis in a Reef-Building Coral

Increasing sea surface temperatures precipitated by rising atmospheric carbon dioxide pose the greatest threat to coral reefs, as prolonged thermal stress causes coral bleaching—the breakdown of the symbiotic relationship between the coral host and its algae (Symbiodiniaceae). Predictions of the likelihood and extent of bleaching have typically considered the duration and magnitude of elevated temperatures relative to a locally defined threshold. However, recent work suggests that heterogeneity in coral bleaching patterns may be better explained by the degree of diel temperature variation typical on a given reef. Here, we conducted a 50-day common garden experiment to assess the influence of low, moderate, and high (2, 3, and 4 °C, respectively) diel temperature variation on the growth and performance of the thermally tolerant, reef-building coral *Siderastrea siderea*. Corals were sourced from six sites differing in thermal regime, light availability, and reef zone in Bocas del Toro, Panama. We found that corals from more thermally variable sites calcified at higher rates when compared to those from less variable sites, regardless of experimental treatment, suggesting that a history of exposure to large and frequent fluctuations in temperature enhances coral growth. Overall, corals subjected to moderate (3 °C) diel temperature variation had the highest symbiont densities and corals in the high variability treatment (4 °C) had the highest growth rates, suggesting that short term exposure to diel temperature variation may also facilitate enhanced growth and symbiosis. Our data support the hypothesis that diel thermal variation on the coral's native reef may play a central role in susceptibility to thermal stress.

66-4 BENTLEY, BP*; MITCHELL, NJ; WHITING, SD; University of Western Australia, Perth, Aus, Department of Biodiversity, Conservation and Attractions, Perth, Aus; *blairbentley@westnet.com.au*

End of the line? Nesting phenology shifts unable to mitigate adverse impacts of climate change on winter nesting sea turtles

Understanding how climate change will affect sea turtle nesting beaches is a fundamental consideration for threat abatement and species recovery plans. Increasing ambient temperatures are expected to lead to increased embryonic mortality and wide-scale rookery feminization for all sea turtle species, threatening population persistence. These effects will vary between species and populations as a consequence of existing environmental heterogeneity, regional differences in the magnitude of climate change, and population-specific thermal thresholds. We employ a mechanistic modelling approach to assess the impacts of climate change on embryonic mortality and sex ratios at four flatback (*Natator depressus*) and two green (*Chelonia mydas*) sea turtle rookeries. The model provides an overview of rookery outputs over a broad spatial-scale at typical nest depths, using temporally robust interpolated climate surfaces. We show that climate change will have the greatest impact on winter nesting populations of *N. depressus* in the tropical north of Western Australia. These rookeries are most susceptible as sand temperatures at nesting depths are generally warmer than other rookeries, and their current nesting phenology does not allow for temporal shifts in nesting to a cooler period of the year. In contrast, summer nesting populations of both *N. depressus* and *C. mydas* appear to be less at risk from increasing ambient temperatures, due in part to their slightly higher thermal thresholds and because they can alter their nesting phenology to avoid suboptimal temperatures. Taken together, our findings demonstrate the need for population-specific models to guide the most appropriate conservation strategy.

108-5 BENTZ, AB*; RUSCH, DB; ROSVALL, KA; Indiana University; *bentza@iu.edu*

Seasonal Shifts in Neural Gene Expression in a Territorial Female Songbird

Seasonally breeding animals commonly display peak aggression early in the breeding season during periods of social instability, with declining aggression during later parental stages. Decades of research suggest that seasonal changes in systemic testosterone (T) levels may influence this behavioral pattern in males, but it is unclear if similar mechanisms apply to females. Tree swallows (*Tachycineta bicolor*) are an emerging model organism for understanding female aggression because females fiercely compete for limited nesting cavities. Aggression in these females is partly mediated by T, and T levels decline sharply in later breeding stages (i.e., during incubation), when elevated T can reduce maternal care. Nevertheless, females retain the ability for robust aggression during incubation, suggesting a seasonal shift in the mechanisms regulating aggression. Here, we begin to address this issue using RNA-seq to explore seasonal patterns of gene expression in the female brain. We found hundreds of genes that were differentially expressed between territory establishment and incubation in the medial amygdala and hypothalamus. During territory establishment, we found greater expression of steroid-related genes, such as 5alpha-reductase, which converts T to the potent androgen dihydrotestosterone, whereas incubating females had greater expression of genes involved in nonapeptide-related signaling. These findings are consistent with a seasonal shift in mechanisms of aggression, a view that is further supported by gene network analyses. Collectively, these data highlight important gene regulatory mechanisms that may underlie behavioral plasticity in females, while also accommodating their maternal roles.

116-5 BERGMANN, PJ*; BERRY, D; Clark University; *pbergmann@clarku.edu*

Effects of head shape on granular substrate penetration performance in fossorial lizards

Squamate reptiles (lizards and snakes) are a morphologically and ecologically diverse clade, and within it fossoriality has evolved multiple times independently and defines the ecology of hundreds of species. Most of these species use their heads as the primary organ for penetrating the substrate. Nevertheless, little is known about what characteristics make an animal proficient at penetrating granular substrates with their heads, and no large-scale evolutionary functional morphological studies have been undertaken. Here we characterize head shape variation in 152 species of fossorial lizards along three fundamental axes of head shape: diameter, slope/taper, and pointiness. We then construct 28 mechanical models spanning the evolved variation, but manipulating these three measures independently, and drive these models into a variety of granular glass bead and natural rock substrates using a linear actuator, while measuring penetration force. Evolutionary correlation analysis shows weak negative relationships between pointiness and the other two measures, and a weak positive relationship between diameter and slope, but none of these are significant, likely showing that different fossorial animals use different strategies. Our mechanical model experiments show that the force needed to penetrate the substrate decreases in finer particles, and for narrower heads that have a shallower slope. Pointiness has the smallest effect, but this effect increases in natural rock substrates and for wider heads, situations where substrate jamming may be considerable. In these cases, pointier heads lead to lower penetration forces. Interactions among main effects were much larger in rock substrates than bead substrates, indicating a more complex behavior in natural substrates.

P3-135 BERGSTROM, CA; Univ. of Alaska Southeast, Juneau; *cabergstrom@alaska.edu*

Are ecological consequences of whole-body asymmetry polymorphism similar in both derived and basal flatfish species?

The link between morphological variation and divergence in niche space partly depends on functional significance of the trait in question. Flatfishes (Order Pleuronectiformes) possess novel morphological variation in the form of whole body asymmetry not seen in other vertebrates. If and how this trait affects ecological diversity within the order is not well understood. Asymmetry direction varies among species and to date there is little known of how direction might impact the function, ecological niche, and adaptive landscape of these fishes. Only seven of >800 species of flatfishes are polymorphic for direction of body asymmetry. Two derived congenerics (*Platichthys stellatus*; *P. flesus*) exhibit geographically variable frequencies of left- and right-eyed morphs, and there is evidence of ecological segregation between them. Unlike the geographically variable and unequal frequencies of asymmetry morphs of these derived species, asymmetry morphs of *Psettodes erumei*, a member of the basal family Psettodidae, are reported to be equal in frequency and yet robust reports of this are rare in the literature. This raises the question: is asymmetry polymorphism being maintained by similar evolutionary mechanisms among flatfish species? Here I tested if, consistent with the derived *Platichthys* sp., sidedness is associated with niche divergence within the basal species *P. erumei*. Fish were collected from four localities in Taiwan, Thailand, and Malaysia. Photographs were analyzed for body shape variation, and trophic level was assessed with stomach contents and stable isotope analysis. The degree of divergence between morphs in the basal species *P. erumei* was compared to that within derived species, and insights into the evolutionary mechanisms responsible are discussed.

90-7 BERK, SA*; BREUNER, C; University of Montana; *sara.berk@umconnect.umt.edu*

Resource availabiility, CORT, and fitness in the mountain bluebird (Sialia currucoides)

Researchers have long been interested in relationships between the corticosterone (CORT) stress response and fitness. The CORT-fitness hypothesis predicts that increased environmental challenge leads to elevated baseline CORT and therefore decreased fitness. In contrast, the CORT-trade-off hypothesis predicts that CORT mediates the trade-off between survival and reproduction, and is therefore positively associated with survival and negatively associated with reproductive success. Finally, the CORT-adaptation hypothesis predicts that CORT increases reproductive success through higher energy expenditure towards reproductive behaviors such as foraging or incubation. All three of these hypotheses rely on varying levels of association between resource availability, CORT levels, individual behavior, and fitness. Previous studies have examined individual links, such as between resource availability and CORT, or CORT and behavior, but we lack complete datasets that examine all possible components to support or refute each hypothesis. Here, we present three years of data on a wild population of mountain bluebirds. We will explore associations between territory quality, body condition, CORT levels, and reproductive success to determine the relationship between CORT and fitness. We hope that by measuring all components necessary to evaluate the predictions of the various CORT-fitness hypotheses, we can shed light on complex associations between CORT and fitness.

P3-30 BERLES, P*; HEYMANN, EW; NYAKATURA, JA; Humboldt Universität zu Berlin, Deutsches Primatenzentrum, Göttingen; *patricia.berles@hu-berlin.de*

Differential habitat utilization in two sympatric tamarins (Callitrichidae, Primates) in Amazonian Peru: Leaping behavior and Importance for morphological Studies

Different sympatric species of tamarins in Amazonian Peru form mixed-species groups during daily forages in the rain forest. These closely-related species have previously been documented to exhibit differences in foraging height and locomotor activity which may also be reflected in their postcranial morphology. To further investigate this system, we quantified habitat utilization with a focus on leaping behavior in free-ranging *Saguinus mystax* and *Leontocebus nigrifrons* . The aim of the work was to determine the relationship of leaping behavior with habitat use and how this is determined by the properties of the habitat. We collected data on the leaping behavior, support properties, and foraging height of the monkeys during a 5-month field study in the Amazonian in northeastern Peru at the Estación Biológica Quebrada Blanco. Our results showed that *S. mystax* spends significantly more time in the upper forest strata and uses the predominant supports at a noticeably higher rate than *L. nigrifrons* . In contrast, *L. nigrifrons* is predominantly active in the lower forest strata and accordingly exhibits a high number of trunk-to-trunk leaps. However, both species preferred their predominant leaping behavior even if the respective supports were not abundant in a specific forest layer. We hypothesize that these observed behavioral differences also involve differential functional demands caused by kinematic and dynamic differences in horizontal and vertical leaps, respectively. Based on these findings morphological differences in muscle architecture, bone shape, and bone structure can be expected and will be traced down in ongoing analyses.

17-1 BERNSTEIN, JM*; CRAWFORD, CH; WAINWRIGHT, DK; RUANE, S; FLAMMANG, BE; Rutgers University-Newark, New Jersey Institute of Technology, Harvard University; *jmbernst223@gmail.com*

Snake Scale Keels: A Three-dimensional Investigation of Function

Keels are raised structures or ridges that are found on the scales of many squamate taxa. Morphological examinations have noted keels in species descriptions for centuries, and it is well known that there is variation in keel structure and number across different squamate lineages adapted to different environments, especially taxa associated with swimming and semiaquatic habitats. Although the presence of these keels is well documented, the functionality of keels remains poorly known for the majority of squamates. In this study we assess the functionality of scale keels in snakes using flow visualization methods. We first microCT scanned 15 snakes with smooth and keeled scales from different habitats (e.g., terrestrial, aquatic) and 3D printed the CT scans. The 3D models were then placed in a flow tank for volumetric particle image velocimetry analysis (3D PIV). The results of these analyses suggest that keels accelerate water flow around scales and may help to reduce drag. Three dimensional surface topologies were visualized using Gelsight and show a diversity of overall surface microstructure and keel structure in snakes that live in different habitats. Future research will examine the microstructure of keeled and smooth scales in terrestrial and aquatic taxa to better understand the functionality of keels on reptiles in non-aquatic environments. This project represents the first study that investigates the function of keels and expands our knowledge on the evolutionary adaptations of squamates.

P1-122 BERSIN, TV*; CORDOVA, KL; JOURNEY, ML; BECKMAN, BR; LEMA, SC; Cal Poly, San Luis Obispo, NOAA Fisheries, NOAA Fisheries; *tbersin@calpoly.edu*

Effects of nutritional stress on the sensitivity of liver IGF-1 production to GH in a Pacific rockfish

The growth hormone (GH) / insulin-like growth factor-1 (IGF-1) axis regulates somatic growth in vertebrates by activating growth-promoting pathways in almost all tissues. Nutritional stress in the form of reduced food quantity or quality has been shown to inhibit growth in part by blocking GH induction of hepatic IGF-1 production, but the mechanism(s) of that inhibition are not well understood. Here, we examined how food deprivation (fasting) affected GH induction of liver IGF-1 production in juvenile gopher rockfish, *Sebastes carnatus*. Rockfish were maintained under conditions of either feeding (9% mass fed per g fish mass) or fasting for 14 d, and then injected intraperitoneally with recombinant seabream GH (2 µg per 1 g mass) or saline control. Liver IGF-1 mRNA levels were generally lower in fasted fish than in fed fish, and GH upregulated hepatic IGF-1 mRNAs 2.2-fold in fed fish, but only 1.4-fold in fasted fish. Liver mRNA levels for two proteins that mediate downstream effects of GH in the liver, janus kinase 2 (JAK2) and signal transducer and activator of transcription 5β (STAT5β), did not vary with fasting or GH treatment. However, transcripts encoding hepatocyte nuclear factor-3β (HNF3β), a transcription factor linked to IGF-1 expression, were at higher abundance both in fed fish and in fish receiving GH. Transcripts encoding IGF binding protein acid labile subunit (IGFALS), which enables IGF-1 interactions with IGF binding proteins, were unaffected by fasting, but increased in both fed and fasted fish treated with GH. These findings point to the downregulation of distinct pathways involving HNF3&beta and IGFALS as possible contributors inhibiting liver IGF-1 production under conditions of nutritional stress.

P2-174 BERTUCCI, EM*; MASON, MW; RHODES, OE; PARROTT, BB; Univ. of Georgia; *emily.bertucci@uga.edu*

Effects of low dose irradiation on the global DNA methylome in medaka (Oryzias latipes)

Ionizing radiation (IR) is a ubiquitous environmental stressor under which all life evolved. Further, radiological accidents at Chernobyl and Fukushima along with occupational and biomedical exposures are sources of IR that humans and wildlife must contend with. Historically, studies on the impacts of radiation have primarily focused on mutagenic effects and responses to acute doses of radiation, thus, adaptive organismal responses to environmentally relevant exposures are not well understood. Epigenetic mechanisms are capable of mediating organismal responses to environmental factors and DNA methylation plays important roles in gene regulation and promoting chromosomal stability. Further, although evidence is limited, studies suggest that variation in the DNA methylome might be heritable across generations. Here, we analyze changes to the DNA methylome due to low dose rate exposures in medaka (*Oryzias latipes*). We hypothesized that low, chronic doses of IR would result in global shifts in the DNA methylome. To test this, medaka were exposed in a replicated mesocosm array to environmentally relevant dose regimes (2, 20, or 200 mGy/day) and were subsampled at three- and six-months. In addition, following a six-month exposure, a subset of fish were allowed a three-month recovery period and were bred to produce an F1 generation. Global DNA methylation was quantified in hepatic tissues across all doses at all time points. Whereas gonadal regression was observed in fish exposed to the highest dose rates, a significant effect of dose on global DNA methylation was not detected. Findings suggest that phenotypic impacts of IR were not mediated by global shifts in the DNA methylome in our study.

69-2 BETZ, O*; HEETHOFF, M; GARAMSZEGI, LZ; KOERNER, L; University of Tübingen, Germany, Technical University of Darmstadt, Germany, Estación Biológica de Doñana-CSIC, Spain, Frau; *oliver.betz@uni-tuebingen.de*

The beetles with the protrusible tongue: Integration of form, function, and ecology in the predatory rove beetles Stenus spp.

The rove beetle genus Stenus has experienced a tremendous radiation, comprising > 3000 species widely distributed throughout the world. Its evolutionary success can be partly attributed to specific morphological features, two of which will be in the focus of this contribution: (1) the labium, or lower lip, is modified into a prey-capture apparatus that can be rapidly protruded a long distance out of the body to stick onto elusive and quick-moving prey such as springtails; (2) proceeding from a phylogenetically antecedent condition with slender tarsi, the tarsi of most species are widened and distinctly bilobed. Based on studies on the functional morphology and ultrastructure of these two organs, comparative experiments on their performance capacity were carried out to elucidate their adaptive value. The direct relationship between morphology, behavior and performance was studied by using phylogenetic generalized least squares and a molecular phylogeny generated from mitochondrial cytochrome c oxidase I partial sequences. The prey-capture success of the labium compared to that of the mandibles suggest that the specialized labial apparatus of Stenus beetles provides an ecological advantage in that it permits these predators, in spite of the limited reaction ability and agility of many Stenus species, to catch prey that are capable of sudden and rapid escape behaviour. Interspecific differences in the adhesive forces generated during the predatory attack entail significant differences in the prey-capture success. In terms of the tarsi, the main selective demands driving their widening in several lineages have probably come from their firm attachment to smooth plant surfaces.

59-5 BHANDAWAT, V*; TAO, L; OZARKAR, S; Duke University; *bhandawat@gmail.com*

Transformation from Sensation to Action in the Drosophila Olfactory System

To understand how odors affect a fly's locomotion, as well as the role of various olfactory neurons, we made two innovations: 1) we created an arena in which a fly's locomotion could be studied under precisely controlled stimulus condition. 2) we created a generative model for a fly's locomotion. We discovered that a fly's locomotion can be decomposed into discrete units, called locomotor features. Odors affect locomotion by altering the fraction of time that a fly spends performing each locomotor feature. The effect of odors on locomotor features is modular: each odor activates multiple olfactory neurons, and a different (but overlapping) subset of neurons affects each locomotor feature. We also investigated the role of two brain regions, the mushroom body (MB) and lateral horn (LH) in odor modulation of locomotion. Based on preliminary experiments, we hypothesize that: 1) LH mediates sensorimotor transformation linking the presence of a particular odor to a particular locomotor parameter, 2) MB combines the ongoing sensory experience with current demands and stimulus history to modulate locomotion. We present preliminary evidence that supports this hypothesis: These evidences come from experiments in which we activated and inactivated small populations of MBONs and LHONs to assess their effect on behavior. Another line of evidence come from recording from MBONs and LHONs to evaluate how they encode sensory input and motor output. Our findings have significance beyond olfaction. Our finding of modularity underlying complex behavior has important implications for how complex behaviors are executed by the brain. Moreover, locomotor features describe how behavior is organized over 10-300 steps. To our knowledge, this is the only quantitative description of the control of locomotion on this relatively long timescale.

93-6 BHANDAWAT, V; Duke University, Visa; *vb37@duke.edu*

Principles underlying control of multi-jointed limb

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 and biomechanics to determine the respective contribution of circuits in the brain, the thoracic ganglia, sensory feedback and biomechanical properties of the limb 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 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 structure movement into alternating stance and swing phases. We use this framework to underpin the role of descending neurons (DNs) from two different parts of the brain in shaping motor output by recording from them while measuring leg kinematics. In sum, there is a division of labor between feedforward and feedback which represents an elegant solution to the "degrees of freedom" problem.

46-6 BIERBAUM, E/L*; BEACHY, C/K; DIAZ, R/E; Southeastern Louisiana University; *Emily.bierbaum@gmail.com*

Unexpected Mesopodial and Digit Number Skeletal Variation in the Elongated and Limb Reduced Amphiuma Salamanders

Tetrapods primarily present a pentadactyl plan. However, limb/digit reductions can correlate with trunk elongated or miniaturized body plans. The typical pattern of digit appearance in amniotes and anurans is posterior to anterior (5 to 1), with digit loss occurring in a reverse anterior to posterior direction (1 to 5). Only in salamanders does the pattern of digit appearance differ, following an anterior to posterior (1 to 5) direction. Within extant salamanders, the Family Amphiumidae presents a unique system to study the evolution and development of limbs due to their very elongated body as well as having reduced limb length and digit number in a graded fashion within the genus: *Amphiuma tridactylum* (Three-toed), *A. means* (Two-toed), and *A. pholeter* ("One-toed"). Ancestrally, salamanders have lost digit 5 in the forelimb, yet retain the pentadactyl pattern in the hind limb. Ancestrally in the genus *Amphiuma*, the forelimb has lost digit 4 while the hindlimb has lost digits 5 and 4 with subsequent reduction within the genus toward a total of 3, 2 and "1" digits per autopodium. Our preliminary data show variation in digit number within each species, and has led us to examine mesopodial skeletal variation to provide insight on which digits were lost. Ultimately, the mesopodial skeleton should provide support for the homology of the retained digits. Our results for *A. tridactylum* show an increase in carpal/tarsal skeletal variation and loss of distal carpal and tarsal 3, which also lacks digit 3 and is thus convergent with *A. means*. In addition, *A. pholeter* was found to consistently present two digits bound in syndactyly rather than the previously assumed one digit.

74-7 BIGMAN, JS*; PARDO, SA; PRINZING, TS; WEGNER, NC; DULVY, NK; Earth to Ocean Research Group, Simon Fraser University, Burnaby, BC Canada, Department of Biology, Dalhousie University, Halifax, NS, Canada, Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, USA; *jbigman@sfu.ca*

Ecological lifestyles and the scaling of shark gill surface area

Fish gill surface area varies across species and with respect to ecological lifestyles. The majority of previous studies only qualitatively describe gill surface area in relation to ecology and focus primarily on teleosts. Here, we quantitatively examined the relationship of gill surface area with respect to specific ecological lifestyle traits in elasmobranchs, which offer an independent evaluation of observed patterns in teleosts. As gill surface area increases ontogenetically with body mass, examination of how gill surface area varies with ecological lifestyle traits must be assessed in the context of its allometry (scaling). Thus, we examined how the relationship of gill surface area and body mass across 11 shark species from the literature and one species for which we made measurements, the Gray Smoothhound *Mustelus californicus*, varied with three ecological lifestyle traits: activity level, habitat, and maximum body size. Relative gill surface at 5,000g ranged from 4,724.98 to 35,694.39 cm^2 and varied across species and the ecological lifestyle traits examined. Specifically, larger-bodied, active, oceanic species had greater relative gill surface area than smaller-bodied, less active, coastal species. In contrast, the rate at which gill surface area scaled with body mass (slope) was generally consistent across species (0.85 ± 0.02) and did not differ statistically with activity level, habitat, or maximum body size. Our results suggest that ecology may influence relative gill surface area, rather than the rate at which gill surface area scales with body mass.

125-4 BIGMAN, JS; PRINZING, TS*; WONG, S; VANDERWAL, W; DULVY, NK; Simon Fraser University; *tprinzin@sfu.ca*

Elasmobranch metabolic rate in an ecological and evolutionary context

Metabolic rate is a fundamental physiological trait that governs resource uptake and allocation, and is well known to vary with body mass and ecological lifestyle traits across species. However, previous studies have only qualitatively examined these relationships in one or a few species, most of which have been teleost fishes. Here, we quantitatively examined the relationship of metabolic rate and specific ecological lifestyle traits in a phylogenetic comparative framework. We examined how the relationship of metabolic rate and body mass varied across the ecological lifestyle traits of habitat type, activity level, and maximum body size in 26 elasmobranch species. We focussed on elasmobranchs because the large variation of ecological lifestyles among species of this group presents an ideal study system. Because metabolic rate increases ontogenetically with body mass, we also assessed the relationship between metabolic rate and ecological lifestyle in an allometric (scaling) context. Our results showed that metabolic rate for a given body mass varied across species and ecological lifestyle traits, while the rate at which metabolic rate increased with body mass remained consistent. This suggests that while metabolic rate for a given body mass is greater in larger, active, and oceanic species compared to smaller, less-active and coastal species, the rate at which metabolic rate increases ontogenetically may be driven less by ecology and more by shared evolutionary history.

P2-128 BILYK, KT*; CHENG, CH-C; Western Kentucky University, University of Illinois at Urbana Champaign; *kevin.bilyk@wku.edu*

Evolutionary Impacts of Chronic Cold on the Antarctic Notothenioid Chaperome and its Regulatory Mechanisms

Antarctic notothenioid fishes show a variety of extraordinary physiological gains and losses driven by their evolution in the chronic cold waters of the Southern Ocean. Both these gains and losses are mirrored in the chaperome, where impacts are found both in expression at native temperatures as well as its capacity to reorganize expression in response to heat stress. While past work has suggested that greater native expression of some molecular chaperones coexists with the extraordinary loss of the Heat Shock Response (HSR), a clear understanding is lacking in the nature and extent of changes across the diverse families of molecular chaperones, and within the regulatory framework controlling their expression during periods of cellular stress. Using the basal temperate notothenioid Eleginops maclovinus as the reference ancestral notothenioid state, we found widespread increases in native expression of chaperome and key proteostasis genes in the Antarctic species Pagothenia borchgrevinki and Chionodraco rastrospinosus. However, these increases are generally small the sole exception is one ancestrally inducible member of the HSP70 gene family, which interestingly correlates with the insertion of a transposon into the gene's 5'UTR intron. In both known copies of ancestrally-inducible HSP70 genes, canonical Heat Shock Element motifs are conserved in the proximal upstream sequence, suggesting defects leading to HSR loss reside elsewhere. Investigation of the coding sequence for the transcription factor HSF1, central in the HSR, showed that modifications among the two Antarctic species were concentrated in the regulatory and transactivation regions of the gene suggesting HSR loss may lie at the level of HSF1 activation of the cascade.

P3-54 BIONDI, AA*; BEMIS, KE; CRAWFORD, CH; FLAMMANG, BE; New Jersey Institute of Technology, Virginia Institute of Marine Science; *aab53@njit.edu*

Mola mola Mismatched Muscle Mechanics

Mola mola (Ocean Sunfish) fish are recognizable by their distinct morphological characteristics, including large lobate dorsal and anal fins which fuse in place of a non-existent caudal fin. *Mola mola* swim using synchronous flapping of the dorsal and anal fins, which generates lift-based thrust similar to the swimming of penguins and manta rays. The Ocean Sunfish is able to dive to depths of 600 meters and cruise at a speed of 3.2 km/h. Recent work on *M. mola* anatomy shows extremely disproportionately sized muscles inserting into the relatively equal aspect ratio dorsal and anal fins. This raises the question: how do *Mola* generate equal forces through synchronous flapping if the muscle mass powering the dorsal fin is nearly twice that of the anal fin? To elucidate the locomotor biomechanics of this large species, we microCT scanned two *M. mola* specimens and dissected two *M. mola* to measure muscle mass, muscle fiber angles, and physiological cross-sectional area (PCSA) to estimate maximum force production. Here, we present the results of our myological investigation and our biomechanical model explaining locomotor force generation in *M. mola*. This work will directly inform the design and actuation of our bioinspired Molabot, which we will use to empirically test the relationship between fin muscle force production and swimming thrust in these unique swimmers.

P2-137 BIRCH, S*; PLACHETZKI, D; University of New Hampshire, Durham , University of New Hampshire, Durham; *sjb1061@wildcats.unh.edu*

The Genomic Characterization of Larval Settlement in the Biofouling Invertebrate Ectopleura larynx

The hydroid *Ectopleura larynx* has an indirect lifecycle that produces a dispersive larval stage called actinula. Actinulae larvae select the substrate upon which they settle by integrating sensory cues from the environment. Previous research has investigated the settlement biology of actinulae larvae, however, to date, no study has combined sensory behavior experiments with molecular genetics. Here we examine the molecular genetics underlying the behavioral response to environmental cues during settlement of actinula larva. We hypothesize that that light and biofilm-derived chemical cues are detected by cnidarian opsin and T1R taste receptors respectively and that these genes will be differentially expressed in sensory neurons as actinula development proceeds to settlement. We test these hypotheses using RNAseq on various stages of actinula development through settlement and combine these data with behavioral experiments that examine the effects of light intensity, wavelength and biofilm-derived chemical cues on the propensity to settle. In addition to behavioral experiments, we incorporate confocal imaging of actinula larva at various stages. We integrate these data to shed light on the interplay between behavior, genetics, and the sensory environment in the settlement of the actinula larva of *Ectopleura*.

P1-13 BIRD, NC; Univ. of Northern Iowa; *nathan.bird@uni.edu*

The Ever-Evolving Comparative Vertebrate Anatomy Final Project: An Alternative to Comprehensive Lecture Finals

Classic methods of assessing comprehensive knowledge in courses such as Comparative Vertebrate Anatomy usually entail a cumulative final exam, where all information presented during the semester is fair game. This can have several drawbacks for many students, due to the considerable length of time that has passed since the first few lectures, and the anxiety that comes with a high-stakes final. In many cases, such an exam tests the student's ability to memorize, rather than learning and mastery of content. Over the past several years, I have experimented with an alternative to the final exam, centered on a "Make Your Own Species Project" concept. This project utilizes inquiry-based learning in a student-centered learning setting. Students either choose or are assigned a current living vertebrate, and must research the anatomy of this species to set the ancestral morphology. Students then imagine a descendent species 100 million years in the future possessing different locomotion, diet, and size relative to their ancestral species. From there, the students have control of what exact changes are made, and how to make it all work, accounting for function and evolutionary process along the way. To encourage students to think outside the box, a single ‘novelty' is allowed, which is exempted from the evolutionary rule requirement. In this way, students must continually refer back to previous anatomical systems to ensure changes in one system don't require necessary changes in a previous system, encouraging a deeper understanding of how the vertebrate body is integrated across multiple systems. In the past, students have sketched their creations or paired with a student from the arts. Currently, students are utilizing Micro-CT and 3D printing to create their new species and bring them to life.

P3-179 BITTENCOURT, JB*; ARMFIELD, BA; STANLEY, EL; COHN, MJ; University of Florida; *juliabitt@ufl.edu*

Nanoscale Computed Tomography (NanoCT) Analysis of Lower Genitourinary Tract Development

Congenital malformations in the genitourinary system occur at a high frequency, yet our understanding of the molecular development of the lower urinary tract lags significantly behind other systems. As an example, hypospadias, a condition in which the urethral opening of the penis is on the underside rather than at the distal tip, occurs in approximately one out of every 120 live male births, yet the developmental etiologies remain unknown. To better understand the morphological and molecular changes that occur to the lower urogenital tract during development we are working on the Genitourinary Development Molecular Anatomy Project (GUDMAP, www.gudmap.org). GUDMAP is a NIDDK U01 consortium of laboratories that provides the research and clinical communities with tools to facilitate genitourinary research. Our lab has combined non-invasive imaging using nanoCT scans with histological and molecular methods for analyzing morphological changes throughout embryonic development in both male and female genitourinary tracts. NanoCT scanning acts as a nondestructive method of high resolution, three-dimensional analysis of genitourinary organ development that will inform our understanding of normal organ formation and will enable the identification of abnormal developmental processes in congenital disorders and deformities in future research.

121-5 BLAIMONT, P*; DUPOUÉ, A; MILES, DB; CLOBERT, J; SINERVO, B; Univ. of California, Santa Cruz, CNRS, Moulis, France, Ohio University; *pblaimon@ucsc.edu*

Effects of basking opportunity on gestation and offspring phenotype of the common lizard (Zootoca vivipara)

Studies investigating the effects of changes in temperature on all life forms are becoming more numerous to better understand their adaptive potential in the face of climate change. Ectotherms are of particular concern because they need to thermoregulate to carry out basic functions and how or if they will be able to adjust to a changing climate is, as yet, unknown. The viviparous lizard (*Zootoca vivipara*) is a common ectothermic species, with a wide geographic range throughout Europe and Asia, allowing us to evaluate a variety of microhabitats ranging in elevation, substrate, and water availability. We collected gravid female lizards from 21 localities, representing different elevations and water availability, in the Cévennes of south-central France as part of a long-term monitoring study during the breeding season in 2017 and 2018. In the lab, females were measured for thermal preference before being randomly assigned a treatment of either 3-hours (low), 6-hours (control) or 9-hours (high) of basking time. We hypothesized that gestating females from lower elevation (warmer) populations would have significantly shorter gestation times and be most affected by the treatments. Offspring were measured for various morphological traits and thermal preference before being released with the females at their site of capture. Preliminary results show sex-dependent differences in offspring size between basking time treatments. In addition, parturition dates, both in number of days and range, also differed significantly across populations and among treatments.

P1-147 BLENDERMAN, J P*; GUMM, J M; Stephen F. Austin State University, Stephen F. Austin State University; U.S. Fish and Wildlife, Ash Meadows Fish Conservation Facility; *jblenderman@outlook.com*

Personality in the Mantis Shrimp Neogonodactylus oerstedii

Animal personality is frequently defined as the existence of consistent behavioral differences between individuals. A well-studied personality trait is boldness/shyness, with bolder individuals being more willing to engage in risky behaviors. This is often measured through foraging, predation, and startle tests. A growing number of studies suggest the presence of personality among invertebrates, including crustaceans. Different personality types can have differential fitness based on environmental conditions such as predation rates and food availability, and thus, are predicted to coexist when conditions are variable. Mantis shrimps (order Stomatopoda) have a versatile repertoire of behaviors used in shelter defense, foraging, and aggression, providing an ideal system in which to study behavioral variation between individuals. This study investigated individual differences in behaviors that may be associated with boldness in the mantis shrimp Neogonodactylus oerstedii. Three assays were carried out to measure behaviors related to boldness: (1) exploration of a novel area containing an unoccupied shelter; (2) reaction to a startling event, and latency to resume foraging afterward; and (3) response to an invasive novel object. To test for individual consistency, individuals were tested twice in each assay, with no less than 14 days between an individual's first and second trials. Analyses presented will establish 1) if individuals are different from each other, 2) if individuals are consistent in their behavioral profiles, and 3) if there are correlations between behaviors. If these conditions are met, it will indicate the presence of personality in this species.

56-7 BOARDMAN, L*; BAILEY, WD; HAHN, DA; Univ. of Florida, Gainesville, USDA-APHIS-PPQ Center for Plant Health Science and Technology, Miami; *lboardman@ufl.edu*

Amino acid and nucleotide signatures of irradiated insects

Trading fresh commodities increases the risk of introducing potentially invasive pest species to new areas. One way to mitigate the risk is through phytosanitary treatments. The use of ionizing radiation as a phytosanitary treatment is growing in popularity, as it is chemical and residue-free. However, unlike traditional chemicals and fumigants, successful treatments with irradiation leave some insects alive. Although these insects will be unable to produce viable offspring and will eventually die, the presence of live insects at commodity inspection can be of concern to some trade partners. Therefore, there is a need for a diagnostic test to confirm that the insects have been irradiated, and do not pose a risk. Previous research suggests that radiation exposure can increase the amount of free/total amino acids and change the concentration of metabolites. However, there is a lack of consensus between species, and detailed investigation using modern, more sensitive, methods is warranted. To investigate whether metabolic biomarkers could be used as a diagnostic test, we exposed third instar larvae and pharate adults of Caribbean fruit fly, *Anastrepha suspensa*, to gamma radiation (0 to 400 Gy). At various time points after radiation, we measured amino acids and nucleotides (NAD and NADH) with Thermo Quantiva MS and Agilent 1290/6490 LC/MS/MS respectively. We report on whether radiation-induced changes in amino acid and nucleotide composition and/or concentrations can be used to identify irradiated insects.

84-1 BOCK, SL*; LOWERS, RH; RAINWATER, TR; HALE, MD; PARROTT, BB; University of Georgia, Kennedy Space Center, Clemson University; *samantha.bock@uga.edu*

Insights from the field: Using a multi-year dataset of nest thermal profiles to investigate temperature-dependent sex determination in the American alligator

Many non-mammalian organisms lack sex chromosomes and sex is instead determined through genome-by-environment interactions experienced during discrete developmental periods. Temperature-dependent sex determination provides a unique window through which to examine how external stimuli are integrated into physiological responses that shape phenotypic diversity in terms of both inter- and intra-sexual variation. Yet our understanding of these fundamental processes has historically been shaped by experimental studies employing constant incubation temperatures that do not accurately reflect the environments experienced in nature. In order to understand the scope of thermal variation experienced during development by the American alligator, this project uses field data to characterize the nest thermal dynamics of 70 alligator nests monitored over the course of seven years at two geographically distinct sites. These field data demonstrate the variable nature of the thermal environment experienced during development. Interestingly, the majority of alligator embryos experience both male- and female-promoting temperatures during the thermosensitive period in development, frequently within a daily cycle. These findings form the basis for current experiments probing the mechanisms by which these opposing environmental cues are integrated into concerted developmental programs and their consequences for later reproductive function.

P1-173 BOCKRATH, RE*; MARSHALL, CA; GHALAMBOR, CK; Colorado State University; *rachbock@rams.colostate.edu*

The effect of salinity on heterospecific and conspecific aggression in two closely related guppy species, Poecilia reticulata and Poecilia picta.

Behavioral dominance in the form of heterospecific and conspecific aggression between species is thought to be an important ecological process shaping the abundance and distribution of organisms, but few studies have examined how such interactions change across different contexts. *Poecilia reticulata* and *Poecilia picta* are closely related fish species that can tolerate a wide range of salinities, but on the island of Trinidad, *P. reticulata* is confined to freshwater habitats whereas *P. picta* is found in freshwater and brackish water. Here we investigated whether changes in behavioral dominance (measured as aggression) could explain why *P. reticulata* is excluded from brackish water. Levels of aggression were compared within species across two different salinities - their home salinity where they are kept, and the away salinity of 15 ppt. We find no evidence that *P. picta* is behaviorally dominant to *P. reticulata* in brackish water. Instead we observed significant individual level variation, where some individuals were consistently aggressive across different salinities independent of whether they were interacting with hetero- or conspecifics. Such results suggest individual personalities play a bigger role in aggressive interactions compared to species differences.

18-1 BODENSTEINER, BL*; MUÑOZ, MM; Virginia Tech;
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Adaptive Radiation in the Multidimensional Phenotype
Adaptive radiations are considered a special case of evolutionary diversification in which a clade displays exceptional ecological and phenotypic diversity. A common feature uniting studies of adaptive radiation is that the ecology-phenotype connection has been almost exclusively described in terms of morphology. For example, the adaptive radiation of Caribbean anoles is known for the evolution of distinct 'ecomorphs', which are so-named based on the tight association between structural habitat use and morphological traits in these lizards. Despite all of the disproportionate attention that morphological traits have received, it has been well-recognized that physiological evolution along environmental gradients is also a key aspect of the adaptive radiation of anoles. For example, Caribbean anoles have evolved to exploit distinct thermal and hydric microhabitats, and also have diversified along elevational gradients. Here, we compare morphological and physiological evolution in anoles from the Caribbean island of Hispaniola. We discover that physiological diversity is high in Hispaniolan anoles and contributes to within-ecomorph phenotypic divergence. Nonetheless, patterns of physiological and morphological evolution are distinct, such that ecomorphs do not cluster together in physiological trait space. We propose that the exceptional diversity of Caribbean anoles may be driven by the combined influence of physiological and morphological evolution, and that physiological divergence along environmental gradients are an equally important, though less appreciated, aspect of adaptive radiation.

31-8 BOERMA, DB*; CHUNG, CC; BARRANTES, JP; CHAVERRI, G; SWARTZ, SM; Brown Univ., The Peddie School, Univ. de Costa Rica, Univ. de Costa Rica;
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How bats with suction cups land on low-friction leaves
An organism's ecology, morphology, and motion are linked throughout evolution, each influencing and accommodating the others. In the bat *Thyroptera tricolor*, suction cups evolved at the bases of the thumbs and feet in connection with specialized roosts—the protective funnels of furled leaves—and allow these bats to adhere to and move along smooth leaf surfaces. Decades of research into the morphology of these suction discs, as well as ecological and behavioral studies, have failed to describe how *T. tricolor* uses these structures during locomotion. We investigated the biomechanics of landing maneuvers in this species. We measured 3D impact force and kinematics by training wild-caught bats to land on a force plate disguised as a furled leaf while recording the event using multi-camera high speed videography. Landing maneuvers comprised three phases: 1) positioning, 2) ballistic descent, and 3) adhesion. When positioning, bats adjusted their location and body orientation until they were in front of and above the leaf-tube manifold. Once positioned, bats folded both wings to passively descend into the leaf, keeping body orientation relatively constant and horizontal. Bats initiated adhesion to the leaf using both thumb-discs. These first points of attachment acted as fulcra about which the bat rotated to swing the foot-discs into contact with the landing plate. Peak 3D impact force was 7.67 ± 2.84 bodyweights ($n=50$ landings). Compared to bat species with different roosting habits, including several that also roost on foliage, landings in this species employ a unique sequence of body rotations and enact higher peak impact force. We propose that the biomechanics of *T. tricolor* landing maneuvers are strongly influenced by their distinctive roosting ecology.

85-1 BOERSMA, J.*; ENBODY, E. D.; JONES, J. A.; LOPEZ-CONTRERAS, E.; KARUBIAN, J.; SCHWABL, H.; Washington State University, Tulane University;
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Taking a Proximate View of a Female Ornament: Do Androgens Mediate Acquisition of the Ornamented Phenotype in female White-shouldered Fairywrens?
Transitions in avian ornamentation have occurred more frequently in females than in males, and often in the direction of gaining elaborate coloration. Recent studies have begun to uncover the function of female ornaments, yet we know little of the mechanisms that promote their expression and the behaviors that accompany them. Androgens mediate acquisition of male ornamental plumage in several taxa and govern a suite of male-typical behaviors; whether androgens have similar effects in generating elaborate female phenotypes is debated and requires empirical tests. The White-shouldered Fairywren (Malurus alboscapulatus) is sister to a species (Malurus melanocephalus) that expresses androgen-mediated male ornamental plumage. Across populations, female M. alboscapulatus can be cryptically colored or ornamented similarly to males. Ornamented females have higher circulating androgens and are more aggressive to simulated intruders. We address two causal explanations for these correlations: 1) androgens mediate both ornament acquisition and aggression, and 2) ornament expression causes elevated androgens and aggression. We tested these hypotheses by supplementing androgens to unornamented females, causing half of these females to molt in one major component of the ornamental plumage. Androgen-implanted females did not increase aggression during simulated territorial intrusions, but females who acquire ornaments express more pair-coordinated aggressive behaviors. These results suggest that androgens are partially responsible for production of ornamental plumage, and ornament expression itself may be more important for enhancing aggression.

P2-178 BOGANTES, V.E.*; LI, Y.; HALANYCH, K.M.; Auburn University, Auburn University; Yale University;
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Amino acid synthesis facilitates host-symbiont interactions in Lamellibrachia luymesi (Siboglinidae, Annelida)
The siboglinid *Lamellibrachia luymesi* van der Land and Nørrevang 1975 is a tubeworm found on cold seeps in the Gulf of Mexico. Like other siboglinids, *L. luymesi* lacks a digestive system and relies on chemoautotrophic sulfide-oxidizing bacterial endosymbionts for nutrition. Phylogenetic studies show that symbiont lineages are specific to major groups of siboglinids, implying some degree of adaptation by the holobiont to different habitats and resources. Despite previous studies, the dependence and metabolic contributions between the host and symbiont are still poorly understood. A recent study on the hydrothermal vent mussel *Bathymodiolus azoricus* analyzed the amino acid biosynthesis pathway in the mollusk and its bacteria endosymbiont, and found that most of the genes required for the production of amino acids were absent in the host but present in the endosymbiont, suggesting that the symbionts are capable of providing all the required amino acids to the host. Similarly, we hypothesize that *L. luymesi* endosymbionts supply most of the amino acids required by the host. To address this issue, we have sequenced the genomes of *L. luymesi* and its endosymbiont. A "blastp"- based bioinformatic pipeline was used to identify amino acid biosynthesis related genes. Preliminary results show that 95% (73 out of 75) of the genes associated with amino acid biosynthesis were found in the endosymbiont, while only 13% were found in the host. Interestingly, this study suggests evolutionary convergence in the biosynthesis of amino acids between two very different organisms.

P1-283 BOGGS, TE*; POWERS, AK; GROSS, JB; University of Cincinnati; *boggste@mail.uc.edu*

Canal Neuromasts Influence the Development and Position of Suborbital Bones in the Blind Mexican Cavefish, Astyanax mexicanus

The lateral line is a crucial sensory system present in many aquatic vertebrates. This sense enables organisms to detect local changes in water flow and pressure which is vital for predator evasion, prey capture and other social or environmental interactions. This system is substantially expanded in *Astyanax* cavefish compared to closely-related surface-dwelling forms, suggesting this non-visual sensory system is under strong selection in cave forms. Additionally, cave forms also harbor multiple abnormalities in their skulls, specifically in the suborbital (SO) bone complex. Owing to the vicinity of lateral line sensory organs (neuromasts) to the SO bones which underlie them, we explored if there was a developmental interaction between this system and facial bones. We utilized two live fluorescent stains to visualize the lateral line system, and developing bones, to produce a comprehensive longitudinal analysis of bone/neuromast growth within individuals. We discovered that dermal SO bones initiated ossification at the position of specific canal neuromasts. Interestingly, abnormalities in the lateral line led to abnormalities in the SO series. For instance, adjacent bones of the SO series in cavefish frequently fused together. In these cases, the distance between canal neuromasts was significantly shorter than in cases where bony fusion did not occur. We also observed that in certain cavefish individuals, the sixth bone of the SO series was entirely absent. This was only observed when the normally associated canal neuromast was also absent. This work suggests that canal neuromasts provide a fundamental "pre-pattern" for the position of SO bones in vertebrates. Aberrations to this pattern explain multiple abnormalities in the craniofacial complex of an obligate cave-dwelling animal.

65-5 BOLMIN, O; WEI, L; HAZEL, A; ALLEYNE, M; DUNN, A; WISSA, A*; University of Illinois Urbana-Champaign; *awissa@illinois.edu*

Latch and release: how hinge morphology and mechanics enable the explosive click of Coleoptera Elateridae

The maneuverability of insects is enabled, in part, by sophisticated energy storage and release processes involving composite materials and architectures. Click beetles (Coleoptera: Elateridae), for example, use a complex hinge mechanism in the thoracic region to latch and snap their bodies, which when unconfined manifests as a legless jump. Understanding how a beetle can accelerate from a stationary position requires an integrated description of the morphology, architecture, and function of the latch mechanism. In this presentation, we focus on the unique morphology and function of the peg and mesosternal lip, which make up the hinge. We first describe the anatomy in detail and define the most important measurements using environmental scanning electron microscope and Computerized Tomography Scans. We then use beam bending mechanics models to quantify the peg stiffness and its contribution to the sturdy brace position from which the snap initiates. Finally, we used a micro-mechanical experiment to measure the force-displacement characteristics of the snap maneuver. The critical function of this anatomy is comprehensively described for the first time through an integration of specific anatomical morphology and engineering mechanics. Results show that the contact surface area of the peg, as well as the force required to overcome the latching mechanism increase as the mass increases, while the peg bending stiffness decreases with increasing body mass.

65-4 BOLMIN, O*; SOCHA, JJ; ALLEYNE, M; DUNN, AC; WISSA, AA; University of Illinois at Urbana-Champaign , Virginia Tech ; *awissa@illinois.edu*

The click beetle latch mechanism: An in-vivo study using synchrotron x-rays

Click beetles (Coleoptera: Elateridae) have evolved a unique mechanism of jumping without the use of legs. The ‘click' mechanism that produces the jump is a power-amplified system that includes a thoracic hinge, stored energy, and very fast energy release. The hinge is composed of a peg and a mesosternal lip, two conformal parts that allow the body to be locked in a characteristic arched position before the jump. In this presentation, we answer the following questions: What are the kinematics of the latching phase, the cuticular deformation and the hinge's geometry prior to the fast energy release? Thus, we imaged live click beetles (*Melanotus* spp., *Parallelosthetus attenuatus* and *Conodus lividus*) using synchrotron x-rays at Argonne National Laboratory's Advanced Photon Source. The beetles were constrained at the abdomen, allowing only the head and prothorax to rotate around the hinge. Clicks (i.e. energy release) were induced in response to the restraint and by reaction to the x-ray radiation. High-speed recordings of the hinge show, for the first time, high resolution of the latch mechanism of the peg on the mesosternal lip and the contraction of soft cuticle prior to energy release. All videos were post-processed using ProAnalyst, ImageJ, and Matlab to quantify the cuticular deformations and latching kinematics. The path of the peg along the mesosternal lip during the latching phase was measured for all species. The click maneuver is characterized by the geometric angle after which the energy release begins. Power amplification magnitude was quantified by comparing the timing of latching and release phases.

137-5 BONILLA, MM*; SHUBIN, NH; University of Chicago; *mmbonilla@uchicago.edu*

How is the endoderm regionalized in chondrichthyans?

The endoderm, through extensive anterior-posterior (AP) patterning, gives rise to an array of specialized cell types and organs. This regionalization is the result of transcription factors and other signaling molecules being expressed in a highly regulated spatial-temporal manner. While this process has been well characterized in mammals, the same cannot be said for other vertebrates. Here we present a developmental series of the endoderm and its derivatives in the little skate (*Leucoraja erinacea*) and zebrafish (*Danio rerio*). We report expression of genes known to be involved in mammalian gut regionalization to test the hypotheses of their conserved function across jawed vertebrates. We then focus on the development of the unique "spiral valve" structure of the little skate intestine. The unique spiral valve structure may play a role in the ability of chondrichthyans to colonize new niches. Furthermore, understanding how these unique structures develop can help us better understand major developmental changes, for example those that might have occurred in the water-to-land transition of vertebrates.

P1-103 BONKA, A*; WIBBELS, T; NAVARRO, E; MONTANO, J; ROSAS, M; MARIN, G; ACOSTA, H; LOPEZ, M; PENA, LJ; BURCHFIELD, P; ILLESCAS, F; Univ. of Alabama at Birmingham, Gladys Porter Zoo, Brownsville, TX, Gladys Porter Zoo, Brownsville, TX, CONANP, Ciudad Victoria, Tamaulipas, MX, CDEN, Ciudad Madero, Tamaulipas, MX ; *abonka@uab.edu*

Quantifying Arribada Nesting Behavior Using Unmanned Aerial Vehicles (UAVs)

The Kemp's ridley sea turtle (*Lepidochelys kempii*) neared extinction in the 1980s, however due to intense conservation efforts the population has begun to rebound. This rebound has included increasing size of mass nesting events (i.e. arribadas). As the size of the arribadas grows, it is important to understand the dynamics of these mass nesting events. The dynamics of these mass nesting events have implications for the biology and conservation of this species. In the current study commercially available UAVs were used to document the dynamics of a relatively large-scale arribada during the 2018 nesting season at Rancho Nuevo. Two quadcopter UAVs (DJI Phantom 3 Pro, DJI Phantom 4 Pro) were used to survey an arribada nesting area during May 2018. Both quadcopters had 4k video capabilities that recorded to an SD card. The UAVs were flown using the Litchi flight app on an iPad Mini 4 tablet. Videos was analyzed to quantify nesting dynamics during different time periods of the arribada. The results show the utility of using UAVs for documenting the magnitude and dynamics of relatively large-scale arribadas. This research was conducted as part of the ongoing Kemp's Ridley Bi-National Conservation Program.

116-1 BORELA, R*; FROST, JD; Georgia Institute of Technology; *rborelav@gatech.edu*

Geomechanics of earthworm locomotion: understanding how the soil enables annelid self-propelled motion

Annelids such as the earthworm *Lumbricus terrestris* achieve underground locomotion via synchronized expansion-contraction cycles (peristalsis) of their segmented bodies. These animals advance in the subsurface at higher rates than current tunnel boring machines. While the mechanics of their locomotion has been broadly studied from the animal perspective, the soil response - critical to their ability to propel themselves - is poorly understood. The present study is aimed at bridging this gap, by investigating the micromechanical response of granular materials (soil) surrounding the body of a worm in peristalsis. For this purpose, a set of two-dimensional and three-dimensional discrete element model (DEM) simulations were performed. In these numerical models, soil particles are modeled as discrete circles (2-D) or spheres (3-D) subject to contact forces and Newton's laws of motion. For each simulation, a domain representing a volume of soil was generated around a segmented cylinder. Once the domain dynamic forces equilibrated, the segments were expanded following a peristaltic motion akin to that of earthworms. Contact forces between particles and their displacements were tracked, allowing for a deep understanding of how the soil responds to such movement. The results reveal how the anchorage mechanism of worms develops, as well as quantifying the forces supporting the advancement into the subsurface. Finally, the results show that the expansion ratio is fundamental in generating anchorage resistance by inducing different soil responses. It was observed that for small expansion ratios (nearly cylindrical shape), interface friction is the most significant contributor to the anchorage force. As the expansion becomes more accentuated, passive resistance is mobilized resulting in remarkably higher anchorage forces.

18-3 BORSTEIN, S. R.*; MCGEE, M.D.; O'MEARA, B.C.; University of Tennessee, Knoxville, Monash University; *sam@borstein.com*

A classic evolutionary innovation does not lead to increased diversification

Evolutionary innovations, adaptive traits that allow species access to a new niche, are thought to promote diversification in clades that possess them. Pharyngognathy, an extensive series of modifications to the pharyngeal jaws, has been suggested to facilitate diversification by allowing access to novel trophic niches via functional decoupling of prey capture with the oral jaws and prey processing with the pharyngeal jaws. Pharyngognathy has been proposed as a major driver of ecological and species diversity in iconic fish families like cichlids (Cichlidae), wrasses (Labridae), and damselfishes (Pomacentridae). However, the effects of pharyngognathy on diversification have not been tested using modern phylogenetic comparative methods. We generated a time calibrated megaphylogeny of over 10,000 species of acanthomorph fishes with 119 fossil constraints. We used hidden state speciation and extinction models to assess the macroevolutionary impact of pharyngognathy on acanthomorph diversification. Our results strongly support state-independent diversification models, suggesting that pharyngognath taxa do not exhibit higher diversification rates relative to non-pharyngognaths. This is also consistent with results from nonparametric approaches. We discuss possible reasons for why pharyngognaths do not have elevated diversification rates relative to non-pharyngognaths and highlight how pharyngognathy may promote ecological diversity without promoting diversification rate.

P2-246 BOTTON-DIVET, L*; HOUSSAYE, A; HERREL, A; FABRE, AC; CORNETTE, R; Humboldt Universität zu Berlin, Museum National d'Histoire Naturelle Paris, Natural History Museum London; *leo.botton-divet@mnhn.fr*

Integration Across the Mustelids' Locomotor Apparatus (Carnivora: Mustelidae)

The locomotor apparatus is, as is the whole organism, an integrated structure. The co-variation of its parts is regulated. In this context, evolutionary response to a functional demand on a part is limited by the functional demands on the other parts. The integration pattern itself may, however, evolve to allow differential changes in its parts. Specialization of pair of limbs to locomotion in a particular environment should induce a reduction of the overall integration while maintaining a strong integration within the limb itself. We investigated changes in the long bone co-variation pattern in mustelids belonging to four different locomotor ecologies (terrestrial, semi-arboreal, semi-fossorial, and semi-aquatic). Despite the differences in locomotor ecology, mustelids show a strong integration and changes in the co-variation patterns are scaling with the between-species divergence time, with the exception of the (*Mustela putorius, M. eversmanni, M. lutreola*) clade where changes in the co-variation pattern increased strongly in a short amount of time. Allometries have only a low impact on the pattern. The co-variation patterns differ between locomotor ecologies, but few of these variations match the hypothesis of a reduction of integration due to functional specialization. As the definition of the functional modules found in literature comes from the study of terrestrial locomotion, we suggest that future studies on the functional modules during locomotion in other environments might shed a new light on the results of this study.

P2-136 BOUCHARD, SS*; BRODERICK, GA; KIMBERLY, EC; Otterbein University; *sbouchard@otterbein.edu*

Competition and predation induce changes in metabolic rate and organ size in red-eyed treefrog larvae

Amphibian larvae exhibit a high amount of developmental plasticity in response to variable environments. In this study, we examined the effects of competition and predation threat on metabolism and organ size plasticity in red-eyed treefrogs (*Agalychnis callidryas*). Larvae were reared at high and low density in 30 L outdoor tanks at the edge of the rainforest (N = 14 tanks per density) at the Smithsonian Tropical Research Institute in Gamboa, Panama. Half of tanks within each density (N = 7) contained a caged *Belostomatid* predator and half did not (N = 7). Each predator was fed *A. callidryas* hatchlings daily to facilitate the release of kairomones into the tanks. There were significant negative effects of both density and predation on larval growth. The metabolic rates of larvae reared at low density were twice as high as those reared at high density. These metabolic rates were associated with significantly heavier livers, pancreases and brains. There was also a much smaller, yet significant, negative effect of predation on metabolic rate. Predation also induced slightly heavier brains, but had no effect on liver or pancreas size. Differences in metabolic rate may be attributed to organ size plasticity. Additional analyses will include more detailed measurements of brain anatomy and tail morphology.

4-1 BOVE, CB*; DAVIES, SW; RIES, JB; UMBANHOWAR, J; CASTILLO, KD; University of North Carolina at Chapel Hill , Boston University, Northeastern University; *colleenbove@gmail.com*

Ocean acidification and warming impact physiology of the algal symbiont to a greater extent than the host in four common Caribbean corals

Increasing carbon dioxide from anthropogenic sources is of growing concern as global average atmospheric pCO_2 has now increased from a pre-industrial level of 280 µatm to 410 µatm, causing ocean temperatures to rise and pH to decline. Corals are particularly vulnerable to these stressors, most likely due to their reliance on their algal symbionts (Symbiodiniaceae) and their use of carbonate ions in calcification. We conducted a 93-day experiment investigating independent and combined effects of acidification (280−3300 µatm pCO_2) and warming (28, 31 °C) on the physiological responses of the coral host (total protein and carbohydrate) and algal symbiont (symbiont density, chlorophyll content, colour analysis) of four Caribbean coral species (*Siderastrea siderea, Pseudodiploria strigosa, Porites astreoides, Undaria tenuifolia*) from inshore and offshore reefs on the Belize Mesoamerican Barrier Reef System. Results show that coral hosts are generally able to maintain energy reserves under acidification and warming, while symbiont densities decline and become less productive as pCO_2 and temperature increase. These results contrast previous assumptions that coral hosts are more susceptible to ocean acidification and warming than their algal symbionts, and provide valuable insight into the future projections for these Caribbean corals under global change.

P1-259 BOWEN, V; MCMAHON, T/A; BROSNAN, E/B; NORDHEIM, C/L; FERNANDEZ-DENMARK, S*; GRIM, J/M; University of Tampa; *jgrim@ut.edu*

Tissue-specific changes in catalase activity of amphibian hosts during the time course of chytridiomycosis

Chytrid fungus (*Batrachochytrium dendrobatidis*) is globally decimating amphibian populations by disrupting the long-term electrolyte transport gradient of skin tissue, thus hindering osmotic regulation and leading to cardiac arrest. Short term, livers of infected amphibian hosts show changes in gene expression just six days after fungal infection, yet it remains unclear how these changes influence the levels of pro- and anti-oxidant processes in these organisms. The present study utilized controlled, long term (6 week) laboratory infections of Cuban treefrogs (*Osteopilus septentrionalis*) with chytrid fungus in order to explore changes in enzymatic antioxidants and general measures of immune system robustness. We quantified the activity levels of catalase (CAT), a key antioxidant enzyme, in skeletal muscle and liver and used histological techniques to assess changes in densities of immune cells in spleen and liver. CAT activity generally decreased in skeletal muscle, but was increased in liver just 8 days into the six-week infection and remained elevated throughout. Further, granulocyte densities decreased in spleen, revealing a potential loss of overall immune system health following six weeks of infection. Together these preliminary data indicate that infection of amphibians with chytrid fungus results in physiological consequences that are tissue-specific, and also reveal that the activity of CAT is affected relatively quickly after initial exposure.

27-2 BOWEN, V*; MCMAHON, T/A; FERNANDEZ-DENMARK, S; GRIM, J/M; University of Tampa; *jgrim@ut.edu*

The impacts of early life exposure to the broad-spectrum antiparasitic Ivermectin on long-term growth rates, organ growth, and susceptibility to chytridiomycosis in juvenile amphibians

Chytrid fungus (*Batrachochytrium dendrobatidis*- Bd) is decimating amphibian populations globally by disrupting organismal osmotic regulation, leading to cardiac arrest. Many laboratory studies clear amphibians of internal parasites with Ivermectin before beginning disease trials. To date, no study has considered the long-term impacts of this treatment on animal health or long-term disease susceptibility. Consequently, we tracked the effects of early life Ivermectin treatment on growth and mortality rates in Cuban tree frogs (*Osteopilus septentrionalis*) from ages 1-3 years, quantified organ weights, and susceptibility to Bd infection. Untreated individuals had both higher absolute weights at all time points and higher growth rates, relative to treated individuals. At the conclusion of the long-term study, Cuban tree frogs were exposed to Bd for two weeks and the spleen, liver, heart, and other tissue samples were collected and weighed. While Ivermectin dosing is an effective anti-parasitic treatment, we found that early life exposure is likely to have unintended impacts on organismal growth and health.

16-2 BOWERS, JM*; AMARIE, D; SITTARAMANE, V; Georgia Southern University; *jb14710@georgiasouthern.edu*
Using DanioVision as a Novel System to Study Learning in the Dwarf Cuttlefish, Sepia bandensis
The prawn-in-a-tube procedure is a learning paradigm for cuttlefish, where a live prey item is enclosed in a clear tube. After multiple attempts to capture the prey with tentacle strikes, cuttlefish learn the prey is inaccessible, and inhibit tentacle strikes. Adult cuttlefish retain the procedure in long term memory stores, as they remember not to strike up to several days after the initial training. However, development of memory in sub-adult *Sepia* is poorly known, as most cuttlefish research represents one species, *S. officinalis*. We used the DanioVision system to study learning in juvenile dwarf cuttlefish, *Sepia bandensis*. DanioVision is a closed system for high-throughput tracking of small animals. By tracking subject activity levels, behavioral differences resulting from changing stimuli or altered reinforcement schedules can be quantified. We employed the prawn-in-a-tube procedure on 21 day old *S. bandensis* juveniles. We hypothesized that cuttlefish would decrease striking within 10 minute trials, and would retain learning after 20 minute intervals between each consecutive trial. Preliminary results suggest that cuttlefish decrease strikes between 5 consecutive trials, implying that long term memory is partly functional at 21 days in *S. bandensis*. The contingencies under which cuttlefish retain the procedure are less known. Future experiments utilizing electric shock will determine the effects of aversive stimuli on retention. This will be done with a uniquely designed, contact circuit which can be operated to deliver shocks immediately after a strike. We hypothesize that retention will improve for cuttlefish that were shocked during training, when compared to cuttlefish that were not shocked.

S5-9 BOWSHER, Julia H*; TORSON, Alex S; YOCUM, George D; RINEHART, Joseph P; North Dakota State University, University of Western Ontario, Edward T. Schafer Agricultural Research Center, USDA ARS, rd T. Schafer Agricultural Research Center, USDA ARS; *julia.bowsher@ndsu.edu*
Protective Mechanisms During Low Temperature Stress in a Solitary Bee
Most temperate insects spend a majority of their lifespan overwintering and change their physiology to protect themselves from the stress of low temperatures. However, prolonged exposure to low temperatures can still cause damage to insect tissues. We explore the molecular mechanisms that contribute to chill injury, and how exposure to periodic warm temperatures can protect from cellular damage using the solitary bee, *Megachile rotundata*. We found that periodic exposure to warm temperatures up-regulates genes associated with oxidative stress, neural development, and ion homeostasis. Next, we compared these observations during overwintering to a later life-stage that is not physiologically prepared for cold exposure. We found that the protective mechanisms were conserved at the level of the cellular process, but differentially regulated at the transcript level. These results can help inform agricultural management of this bee species and predict response to the temperature fluctuations associated with climate change.

63-6 BOYER, AC*; MACDOUGALL-SHACKLETON, SA; University of Western Ontario; *aboyer@uwo.ca*
Spring and Autumn Temperatures Differentially Affect Nocturnal Migratory Restlessness in a Migratory Songbird
Although the timing of bird migration is broadly controlled by internal and external annual clocks, weather-related factors such as temperature, wind speed and direction, and barometric pressure can influence the timing and success of migratory flights and stopover durations. Weather conditions differ across seasons for many North American songbirds, thus weather cues in autumn may influence birds differently than those same cues in the spring. In addition, the rate and synchrony of migration differs between spring and autumn for many songbirds. To explore how temperature may differentially affect migration across seasons, we experimentally exposed white-throated sparrows (*Zonotrichia albicollis*) to three temperature treatments during both autumn and spring migration and also gave birds a restricted or unlimited diet. We manipulated temperature each night to one of three conditions: 4 °C to represent a cold evening, 14 °C to represent average seasonal temperatures, or 24 °C to represent a warm evening. Each day, birds returned to 14 °C for the remainder of the day. We quantified nocturnal migratory restlessness (*Zugunruhe*) using infra-red video recordings and automated activity tracking software. Preliminary analyses indicate differential effects of migratory restlessness between seasons, with stronger effects of temperature in spring compared to autumn. In addition, we observed sex differences in spring, but not in autumn. These results provide evidence that birds can shift their migratory behavior depending on temperature and suggest that the importance of temperature as a cue for migration timing differs between spring and autumn.

P3-64 BOYNTON, AM*; CARRIER, DR; University of Utah, Salt Lake City; *boynton.alicia@gmail.com*
The locomotor function of cervical muscles in humans
The locomotor function of the neck muscles of humans is not understood. We hypothesized three possible roles: 1) stabilization of the head on the trunk; 2) stabilization of the neck against moments imposed by extrinsic arm muscles, and 3) stabilization of the trunk against torques imposed by extrinsic leg muscles. To examine these hypotheses, we measured activity of several cervical muscles with surface EMG and analyzed changes in activity in response to manipulations of the locomotor forces as subjects ran on a treadmill. To access the postural role of the cervical muscles during running we increased the mass of head by 20%. To address the impact of moments imposed on the neck by swinging of the arms, subjects held their arms at their sides as they ran. To determine the extent by which cervical muscles help stabilize the trunk against moments imposed on the pelvis, we applied forward-, rearward-, and vertically-directed forces to the subject's pelvis with elastic tethers. Muscle activity recorded during manipulation trials was compared to activity recorded during unencumbered running at the same speed. We found no significant change in muscle activity when subjects ran with added head mass or with limited arm swing. Activity increased in the cervical strap muscles when subjects ran with increased forward-directed forces (requiring elevated leg protraction moments) and increased rearward-directed forces (requiring elevated leg retraction moments). Running with added rearward force also resulted in elevated activity of the semispinalis, levator scapulae, and rectus abdominis. These results are consistent with the suggestion that the primary function of the cervical muscles during human running is to help stabilize the trunk against the moments imposed on the pelvis by extrinsic muscles of the legs.

21-7 BRADY, SP*; RAFFEL, TR; Oakland University; *seanbrady@oakland.edu*

Thermal Acclimation Effects on Metabolic Performance in the Mexican Axolotl, Ambystoma mexicanum

Within-season temperature variability is expected to increase as the climate continues to change, making it increasingly important to understand organism responses to sudden temperature shifts. According to the Metabolic Theory of Ecology (MTE), whole-body metabolic responses to temperature can provide useful insights into the potential effects of temperature on physiological performance and ecological processes (e.g., population growth rates). In this study, we assessed how changing temperatures influenced whole-body respiratory rates in the Mexican axolotl, *Ambystoma mexicanum*. Axolotls were acclimated to one of three acclimation temperatures (7, 16, and 25 C) for 3 weeks before measuring oxygen consumption across a range of performance temperatures (7, 10, 13, 16, 19, 22, 25, 28 C), such that all combinations of acclimation and performance temperatures were tested. Axolotl respiratory rates were then measured at the new performance temperatures at 2, 4, and 6 days following the temperature shift. Respirometry data were then used to parameterize thermal performance curves based on the Sharpe-Schoolfield model. Immediately following the temperature shift, cold-acclimated axolotls out-performed warm-acclimated axolotls across the full range of temperatures. However, the cold-acclimated axolotls experienced reduced metabolic performance within a few days of exposure to the warmer performance temperatures, followed by a gradual convergence of performance curves for all acclimation temperatures. These results are consistent with the "colder-is-better" hypothesis of thermal biology, possibly driven by responses to thermal stress (e.g., greater energy expenditure) at higher acclimation temperatures.

P3-93 BRALLEY, JP*; CORY, W; WELCH, AM; College of Charleston; *bralleyjp@g.cofc.edu*

Behavioral Effects of Fluoxetine and Sertraline and their Photodegradants on Southern Toad (Anaxyrus terrestris) Tadpoles

Pharmaceutical pollution is an emerging environmental concern, with a variety of mediations appearing in surface waters around the world. In the environment, exposure to UV radiation can transform these compounds into related molecules, which can be more toxic than the original compound. Despite increased attention to the effects of pharmaceutical pollution on aquatic life, very little is known about the ecotoxicology of pharmaceutical transformation products. Antidepressants, including the widely-prescribed selective serotonin reuptake inhibitors fluoxetine (Prozac) and sertraline (Zoloft), have been regularly detected in the environment and have been shown to cause a variety of behavioral changes in organisms ranging from mollusks to fish to tadpoles. We investigated the effects of these compounds and their UV-phototransformation products on the behavior of amphibian larvae, which are particularly vulnerable to aquatic pollution due to their permeable skin. Southern toad tadpoles were exposed to solutions of fluoxetine and sertraline, with or without phototransformation, and behavioral assays were conducted to examine startle response, aggregation behavior, and refuge use. These behaviors are relevant to sertraline's mode of action, similar to behavioral changes observed in other organisms exposed to similar antidepressants, and potentially important to tadpoles' vulnerability to predation. The results of this research will help us better evaluate the level of risk posed by these antidepressants in the aquatic environment.

P3-76 BRANDFON, SH*; CIRINO, LA; MILLER, CW; University of Florida ; *sbrandfon@ufl.edu*

The effect of juvenile and adult diet on female fecundity and longevity

Environments change seasonally and so do the resources that are provided to herbivores. Prickly pear cactus is a seasonal plant that has unripe fruit (suboptimal) in the spring and ripe fruit (optimal) in the fall. Thus, leaf-footed cactus bugs, *Narnia femorata*, that feed on this plant are subjected to varying nutrition throughout the year. The objective of this study is to understand how separate and combined juvenile and adult natural diets effect the longevity and fecundity of *N. femorata*. Juveniles were placed on either suboptimal or optimal diets. Adult females in the suboptimal group were then split into suboptimal or optimal diets. *N. femorata* were observed every day for feeding and egg laying for 84 days. Preliminary results suggest that females on adult diets are the most fecund and live the longest. Females on suboptimal diets are the least fecund. Females that were switched from a suboptimal to an optimal diet were able to reproductively recover and lay more eggs than the fully suboptimal diet group. This study suggests that animals that have suffered from suboptimal diets as juveniles, will be able to partially recover with an optimal diet in adulthood.

58-5 BRANDLEY, N*; SALAZAR, B; DUNCAN, A; College of Wooster, Colorado College; *nbrandley@wooster.edu*

A sexual dimorphism in the spatial vision of band-winged grasshoppers

Understanding an animal's behavior, ecology, and evolution requires knowing their sensory capabilities. Notably, animal perception can vary not only between species, but also within a species. Here we suggest that male and female band-winged grasshoppers (subfamily Oedipodinae) differ in their visual acuity (spatial vision). We examined three species of band-winged grasshopper that show sexual size dimorphisms. Using the Radius of Curvature Estimation, we measured the visual acuity of the region of the eye with the finest spatial vision (total n = 98). Two species showed significant differences in visual acuity between the sexes, while the third was trending towards significance. Generally the females were both larger than their male counterparts and showed finer visual acuity. Our results show that studies correlating spatial vision to body size across animal species may also apply within a species, and suggests that sex differences in visual acuity may be an underappreciated phenomenon leading to behavioral differences between the sexes.

P3-125 BRANDT, E.E.*; KAMATH, A; ELIAS, D.O.; University of California, Berkeley, Department of ESPM; *eebrandt@berkeley.edu*

Thermal Ecology in Miniature: Microhabitat Usage in the Context of Physiological and Behavioral Performance in a Spider

Temperature can have wide-ranging and dramatic effects on ectothermic animals. These effects span levels of biological organization, from metabolism to interspecific interactions. As deserts have temperatures that can vary widely across temporal and spatial scales, animals living in them particularly interesting to examine in this context. However, there is a gap in knowledge in understanding how thermal microhabitats vary at the scale of the animal in question. These studies are especially lacking among small animals. In this study, we used a focal observation paradigm to investigate activity budgets, substrate use, and sex-specific differences in relevant thermal microhabitats in the jumping spider *Habronattus clypeatus*. We are beginning to gain a nuanced understanding of how temperature influences sexual behavior in this system, so it is especially suited to such field-based studies. We combine field data with lab experiments to explore physiological thermal limits, thermal performance data, and thermal preferences to understand the interplay between these animals' physiological limits, preferences and the environment that they actually experience. We compare behavior, substrate use, and thermal microhabitat use between sexes and life stages, and suggest ways in which thermal microhabitat use in particular may interact with sexual behavior in this species. We suggest that variation in these aspects of thermal ecology could lead to profound downstream effects on behavior, survival, and even species persistence over time.

54-5 BRANNOCK, P M*; LEARMAN, D R; MAHON, A R; SANTOS, S R; HALANYCH, K M ; Rollins College, Central Michigan University , Auburn University ; *pbrannock@rollins.edu*

Meiobenthic community composition and biodiversity along a 5500 km transect of Western Antarctica: a metabarcoding analysis

Meiobenthic organisms, consisting of meiofauna and benthic microeukaryotes, are key components of marine ecosystems and facilitate bentho-pelagic coupling. However, their biogeographic ranges and dispersal abilities are poorly known, especially in Antarctic waters where knowledge is extremely limited. Many Antarctic marine invertebrates are reported to have circumpolar distributions despite lecithotrophy and brooding development being common. Similarly, most meiofauna have developmental stages that are often assumed to have limited dispersal capabilities. To assess Antarctic meiobenthic community distribution patterns and diversity, the hypervariable V9 region of the 18S small subunit ribosomal RNA (SSU rRNA) gene was used to metabarcode shelf sediment samples (water depth 223 to 820 m) across a 5500 km region of the Western Antarctic. We found that some taxa had broad geographic distributions given that 28 operational taxonomic units (OTUs) were present in every core processed, 74 OTUs were found at every sampling event, and 722 OTUs were present in all of the major water basins sampled. Among these broadly distributed OTUs, metazoan taxa from 4 phyla (annelids, arthropods, kinorhynchs, and nematodes) were dominant members. As many of these OTUs relate to taxa expected to have limited dispersal capabilities based on current life history information, these results highlight our limited understanding of how small organisms move around in the sea. We also noted that the Antarctic Peninsula hosts a strikingly different and less diverse community than higher latitude regions in contrast to benthic macrofauna.

P1-236 BRÜCKNER, A; Caltech; *bruckner@caltech.edu*

Using Weapons Instead of Perfume? - How the Myrmecophilus Bug Pamillia behrensii (Miridae) Gets Along With its Host Ant

In and around ant nests such called 'myrmecophilous' animals try to overcome their hosts defense. For those who succeed, the companionship with their host guarantees powerful protection and access to food. As ant defensive behavior is mainly mediated by chemicals - for instance species specific cuticular hydrocarbons (CHCs) or alarm pheromones - ant-associated parasites can either crack their hots chemical code by modifying their own CHC-profiles or use pro-active strategies like chemical weaponry for distraction and repellency. While the chemistry of many ant-parasite interactions has been detailed recently, the chemical mediators of the rare association of ants and ant-resembling Heteropterans are mostly unknown. That is why I studied the mirid bug *Pamillia behrensii* which has been reported to live associated with velvety tree ants (*Liometopum occidentale*) an ecologically dominant and aggressive ant species native to the Southwest. More specifically I used behavioral, chemical and molecular approaches to disentangle the relationship of *P. behrensii* and its host ant. Chemical profiling of cuticular hydrocarbons of both bugs and ants revealed no chemical mimicry, yet additional GC/MS analysis of volatile compounds of the bugs metathoracic glands as well as feeding trials with armed and artificially disarmed bugs showed a defensive function of the gland exudates. Further field observations and first molecular evidence suggest that *P. behrensii* might be a Batesian mimic. In summary, the bugs mainly live loosely associated directly next to ant nests and are regularly aggressed by ants (CHC mismatch). Yet, bugs usually survive and escape these attacks by releasing their defensive chemical as repellents against (host) ants. Hence, the use of chemical weaponry rather than a chemical code-cracking perfume enables *P. behrensii* to get along and live close by its host ant.

126-6 BREDLAU, JP*; KESTER, KM; GUNDERSEN-RINDAL, DE; KUHAR, D; Virginia Commonwealth University, USDA-ARS, USDA-ARS; *bredlauj@vcu.edu*

Asymmetric Hybrid Sterility and Bracovirus Differentiation Among Host-foodplant Sources of the Parasitic Wasp, Cotesia congregata

Parasitic wasps are highly diverse and play a major role in suppression of herbivorous pest populations. Prior work demonstrates that the gregarious endoparasitoid, *Cotesia congregata*, contains two incipient species originating from different host-foodplant complex sources, *Manduca sexta* on tobacco (MsT) and *Ceratomia catalpa*e on catalpa (CcC). Hybrids resulting from CcC male x MsT female crosses are typically sterile. Bracoviruses (BVs) are endosymbionts of braconid wasps that facilitate wasp development by interrupting the immune responses and physiology of parasitized caterpillar hosts. BVs are integrated within the wasp genome and transmitted vertically. BV particles are injected during oviposition, where their encoded virulence genes are expressed in host tissues. Cumulative results to date indicate that some BVs are functional within a limited range of hosts. Several *C. congregata* BV (CcBV) genes differ between MsT and CcC wasps. We compared patterns of relative expression of selected CcBV genes in *M. sexta* and *C. catalpae* parasitized by individual MsT or CcC wasps, and in *M. sexta* parasitized by individual MsT and CcC hybrids, using qRT-PCR. Patterns of *in vivo* expression of CcBV genes from MsT and CcC wasps differed in each host species; a few genes were not detected in hosts parasitized by CcC wasps. Parasitization by sterile hybrids resulted in low or absent expression of CcBV genes. Results further support designation of the two host-foodplant complex sources of *C. congregata* as incipient species.

P3-130 BREITENBACH, AT*; CARTER, AW; PAITZ, RT; BOWDEN, RM; Illinois St U, U Tennessee; *atbreit@ilstu.edu*
Heat Wave Timing, Continuity, and Length Affect Temperature-dependent Sex Determination in a Freshwater Turtle
Climate change has the potential to threaten thermally sensitive species, such as reptiles with temperature-dependent sex determination (TSD), if heat waves increase in frequency and length as predicted. In species with TSD, temperature affects sex determination most acutely during the thermosensitive period (TSP), which falls in the middle third of development as defined by constant temperature studies. Presently, we know little about how the timing during development or continuity of heat waves affects sex determination. We hypothesized that exposure to daily fluctuations of 25±3°C (which produce all males) and heat waves of 29.5±3°C that varied in either timing during development or continuity (in progress) would affect resulting sex ratios in *Trachemys scripta*. Exposure to a 15-day heat wave early or late in development did not significantly affect sex ratios (all less than 10% female), but heat waves occurring between days 24 and 45 resulted in an average sex ratio of 80% female. Further, the observed TSP was shorter than the TSP defined by constant temperature studies. We also quantified *Dmrt* and *aromatase* expression following 6, 9, 12, and 16 days of heat wave exposure to determine how heat waves affect gene expression. *Aromatase* expression was significantly up-regulated after 12- and 16-day heat waves, while *Dmrt1* expression did not significantly change over the course of the heat wave. These results clarify the timing and length of the TSP and provide information on the timing of up-regulation of *aromatase* expression under fluctuating, heat wave conditions. Further, these data provide detailed insight into the physiological effects of climate change, in the form of heat waves, on species with TSD.

53-1 BRESSMAN, NB*; LOVE, JW; KING, T; HORNE, C; ASHLEY-ROSS, MA; Wake Forest University, Maryland Department of Natural Resources; *bresnr16@wfu.edu*
Emersion and functional terrestrial locomotion by the invasive Northern Snakehead, Channa argus
The Northern Snakehead (*Channa argus*) is an ecologically-harmful invasive species to the United States, known for air-breathing capabilities and amphibious behaviors. However, previous descriptions of these behaviors are inconsistent and lack important details. The goals of this study were to quantify the terrestrial locomotion of *C. argus*, compare their locomotor behaviors to other amphibious fishes', determine environmental conditions for emersion, and assess the potential of this species to disperse overland. We quantified kinematics from videos of *C. argus* (TL = 5-70 cm) moving on five terrestrial substrates and recorded electromyograms from axial and appendicular muscles as *C. argus* moved over turf. While *C. argus* perform better on rougher substrates, they always use their pectoral fins and body for axial-appendage-based terrestrial locomotion, with axial kinematics similar to Tidepool Sculpins (*Oligocottus maculosus*), but use both pectoral fins simultaneously rather than alternatingly. However, *C. argus* juveniles <5 cm use tail-flip jumps to move on land, suggesting an ontogenetic shift in terrestrial behaviors. We also exposed individuals to a variety of environmental conditions, such as hypoxia, to determine conditions that promote *C. argus* emersion from the water. In these experiments, *C. argus* fry voluntarily emerged when exposed to extreme environmental conditions, including low pH (pH = 4.8) and hypercapnia. Their functional terrestrial locomotor behaviors, combined with their emersion behavior and efficient air-breathing capabilities, suggests that *C. argus* may be able to colonize new bodies of water via temporary overland movements.

S5-5 BREUNER, CW*; BERK, SA; The University of Montana; *creagh.breuner@umontana.edu*
Links between glucocorticoids and fitness; three hypotheses, lots of data and 10 years later: what do we know, what's next?
Ten years ago two reviews clarified the need to tie glucocorticoid levels directly to survival and reproductive measures. Three primary hypotheses emerged from that work: The CORT-fitness hypothesis, the CORT-adaptation hypothesis, and the CORT-tradeoff hypothesis. Over the last 10 years those two articles have been cited over 800 times, but no clear consensus has emerged supporting one hypothesis over another. We propose that the discrepancy in results may be due to variation in resource availability. In free-living animals, trade-offs may be masked by high resource availability in good years, but evident in poor years. Current literature testing between these hypotheses rarely incorporates metrics of resource availability. In 1986 Van Noordwijk and de Jong proposed the acquisition/allocation model to explain positive vs. negative correlations between reproduction and survival across individuals. Their model identifies resources as critical to evaluating individual allocation strategies (favoring reproduction vs survival), and therefore provides the ideal model for testing across the three CORT hypotheses. Here we will 1) review the three hypotheses in light of the last 10 years of data, 2) review the relatively small subset of fitness/glucocorticoid papers that incorporate a resource perspective, 3) introduce the Van Noordwijk and de Jong framework as a model for fitness/glucocorticoid hypothesis testing, and 4) discuss recent results testing the effects of resource limitation on tradeoffs between feather structure and color in mountain bluebirds (*Sialia currucoides*).

P2-266 BRIGGS-HALE, JM*; ROOT, ZD; MEDEIROS, DM; Univ. of Colorado, Boulder; *julia.briggshale@colorado.edu*
The Evolution of Jaw Joint Precursors in a Jawless Vertebrate
Jaws are an evolutionary innovation found in the majority of vertebrates (gnathostomes) which facilitate the capture of prey. One of its key features is a central jaw joint that allows the articulation of its rigid skeleton, yet we are uncertain as to the origins of this joint. To address jaw joint evolution, we investigated the skeletal development of an early diverging jawless vertebrate, the sea lamprey *Petromyzon marinus*. During their larval stage, their skeleton contains tissue known as mucocartilage that shares morphological and genetic features with the jaw joint. We asked whether mucocartilage may be homologous with joint tissue in gnathostomes by investigating genes in sea lamprey that are related to joint development. To do this, we conducted *in situ* hybridizations on embryos for three genes of interest (BarxA, TrpsA, and GDF5/6/7b). We also performed alcian stains to visualize skeletal development. To assess the function of these genes, we used CRISPR-cas9 mutagenesis to assess differences in gene expression and cartilage development in mutants. Our *in situ* hybridizations show expression of BarxA and TrpsA in both mucocartilage and rigid skeleton, contrasting their more exclusive gnathostome orthologues. These results were reinforced in TrpsA and BarX mutants, which show global loss of cartilage. GDF5/6/7b is expressed early in the anterior head and ventral pharynx, coinciding with future sites of mucocartilage. However, GDF5/6/7b mutants show only a slight loss of these tissues and loss of expression of TrpsA. Our results suggest that genes involved in the vertebrate jaw joint were co-opted from more generalized roles in skeletal development. We discuss how mucocartilage may not be as homogenous as previously thought and how this may shape our understanding of the jaw joint.

S7-6 BRIGHT, JA; University of South Florida, Tampa; *jabright@mail.usf.edu*

A Holistic Approach to the Evolution of Feeding in Birds

With nearly 11,000 currently recognised species, birds (Class: Aves) are the most diverse clade of tetrapods. They possess a highly modified skull compared to the non-avian dinosaurs, with exceptionally thin bone, lightweight construction, and considerable cranial kinesis. The most striking modification to bird skulls, however, is the beak: an expanded, toothless maxillary region covered by a keratinous rhamphotheca. Beaks are highly disparate, reflecting not only the diversity of birds, but also the wide range of feeding ecologies that they operate in. Yet even with such disparity, morphological convergence is rife, and similar beak shapes evolve repeatedly across the avian tree. Well-demonstrated links between beak shape changes and dietary shifts are often assumed to drive high rates of phenotypic evolution, largely thanks to the extensive study of such relationships in classic adaptive radiations like Galapagos finches and Hawaiian honeycreepers. However, these patterns are rarely quantified with a wider lens. By utilising molecular phylogenies and morphometric analyses of up to 5,550 species at a time, it becomes apparent that these ‘classic' radiations are exceptional events that are not characteristic of avian evolution more broadly. Rates of beak shape evolution are not strongly tied to extrinsic factors, and instead are associated with phenotypically unusual clades ‘unlocking' new niches. Within these niches, beak shapes tend to remain relatively conserved, but with significant phylogenetic, allometric, and integrative signals superimposed. Dietary behaviour, conversely, predicts very little shape variation thanks to extensive many-to-one relationships between function and form. Bird beak evolution must therefore be considered more holistically if we are to truly understand how diversity accumulated in this exceptional clade.

P2-159 BRINKLEY, DM*; RIVERA, HE; TARRANT, AM; Amherst College, Woods Hole Oceanographic Inst.; *atarrant@whoi.edu*

Thermal Acclimation in the Anemone Nematostella vectensis

Fundamental to the survival of animals in temperate climates is the ability to acclimate to temperature changes. The metabolic thermal response is relatively well-characterized, and reversible cellular mechanisms of acclimation can be broadly distributed into two categories: changes in mitochondrial density, the size and number of mitochondria in a cell; and changes in mitochondrial efficiency, a variety of factors affecting the ATP production rate of individual mitochondria. Both strategies facilitate thermal acclimation, yet few studies have investigated their timing. How long does the acclimation process take? How do mitochondrial efficiency and density interplay to produce a response over time? These are the questions that we chose to investigate within *Nematostella vectensis*, a small, salt marsh-dwelling anemone that experiences seasonal variation of ≥35˚C. We transitioned animals from 18˚C to six temperatures between 6 and 33˚C and, weekly, assayed two physiological responses: oxygen consumption of individual animals, indicative of the extent of acclimation; and citrate synthase (CS) activity, a standard proxy for mitochondrial density. We hypothesized that animals would acclimate first by altering their mitochondrial efficiency and later by adjusting mitochondrial density. Over six weeks, we found that respiration rates diverge significantly between temperature groups as early as the second week ($p < 0.05$). In the same animals, however, CS activity does not significantly change. This suggests that, though *Nematostella* do acclimate, mitochondrial density does not play a role in their initial acclimation response. Whether they regulate mitochondrial density on longer time scales remains an open question.

P2-56 BRINKMAN, BE*; NGWENYA, A; FJORDBOTTEN, KM; STEPHEN, O; KOLB, B; IWANIUK, AN; Univ. of Lethbrige, Alberta, Rhodes Univ., South Africa; *Ben.brinkman@uleth.ca*

Hippocampal Neuronal Morphology and Spine Density Vary With Sex and Season in Richardson's Ground Squirrel (Urocitellus Richardsonii)

Brain anatomy is not static throughout the lifetime of an individual; both sex and reproductive status can alter the anatomy of brain regions and neurons within them. However, the extent to which sex and season affect neuron size and morphology in wild mammals is poorly understood. Richardson's ground squirrel exhibits seasonal variation and sex differences in behavior and seasonal neuroplasticity in brain region volumes, but whether that variation extends to neuron morphology was unknown. Using virtual microscopy, we imaged Golgi stained hippocampal pyramidal neurons from wild male and female ground squirrels caught during breeding and non-breeding seasons. From these images, we measured neuronal morphology and dendritic spine density of over 130 neurons. Within the CA1 region, females had larger cell bodies than males and non-breeding females had longer basal dendrites than breeding females. Dendritic spine density of basal and apical dendrites of CA1 neurons was also higher in non-breeding than breeding animals of both sexes. Within CA3, non-breeding males had larger neuronal volumes than breeding males and non-breeding animals of both sexes had higher basal spine densities than breeding animals. The seasonal differences likely reflect synaptic pruning during hibernation combined with high cortisol levels in the breeding season and parallels a similar pattern in hippocampal neurogenesis. The larger CA3 neurons with more spines in non-breeding males might also support food caching, a male-specific behavior in this species. We conclude that sex and season do interact to affect neuron morphology in ground squirrels, but that these effects are likely to vary across mammalian species.

P1-96 BRISTOW, M.L.*; GABOR, C.R.; HUERTAS, M.; Texas State University; *mlb325@txstate.edu*

Conspecific chemical communication in a live-bearing fish, Poecilia latipinna

Aquatic environments can be dark or turbid, making visual cues difficult to detect. In these cases, chemical communication is advantageous. *Poecilia latipinna*, a live-bearing fish, lives in waterbodies where visual communication is not always reliable. Male *P. latipinna* differentiate between receptive and non-receptive females. Moreover, we have preliminary data that shows males are attracted to female extracts. In other closely related live-bearers, chemical communication is an important factor in female mate choice. We hypothesized that *P. latipinna* use chemical communication to coordinate mating. To investigate this, we did two experiments, observing behavior, endocrine response, and gonadal histology. In the first experiment, we paired a female with two males and recorded mating behaviors for 10 mins. We took pre- and post-mating water samples from each fish to establish a water-borne steroid profile by ELISA. Our preliminary results show complex reproductive behavior in this species, paired with a post-mating decrease of estradiol and progesterone in females; both of which are regulators of ovulation. Additionally, we found that both males and females had relatively high concentrations of glucoronidated prostaglandin F2α (474.20 ± 194.55 ng/L/h/g). Prostaglandins putatively induce ovulation in fish. Therefore, in the second experiment we quantified female physiological response to male chemical cues. We placed each female in 5 L of water, exposed them to male extracts for 4 hours and took water samples at 0h, 0.5h, 1.5h and 4h. After 4 hours, we collected ovaries for histology. We predict to see changes in water-borne steroids and gonadal composition after chemical cue exposure. This study, combined with our previous research, suggests this species uses chemical communication to coordinate mating.

48-5 BRITTAIN, CN*; STILL, SE; MENON, A; CRISTOL, DA; WADA, H; Auburn University, College of William and Mary, College of William and Mary; *cnw0012@auburn.edu*
Dietary Methylmercury Exposure Impedes Spatial Learning in Zebra Finches
Methylmercury is a widespread environmental stressor known to disrupt endocrine and neural function of organisms even with exposure at sublethal levels. Previous studies of its effects on physiology and behavior have focused mainly on aquatic organisms. However, more recent studies have shown that mercury also bioaccumulates in terrestrial food webs. This study sought to discern the effects of sublethal levels of mercury on spatial learning and memory in songbirds, an understudied group exposed to the neurotoxicant. We conducted 5-phase spatial memory trials where captive zebra finches (*Taeniopygia guttata*) learned to find and remember the correct location of food in covered, baited blocks across several days. Zebra finches were either exposed to environmentally relevant levels of methylmercury (1.2 parts per million) or control diet throughout their lifespans. Birds exposed to methylmercury required more trials to learn and return to the location of food than did control counterparts. At the same time, dietary mercury did not affect recall of food location once they had been learned. This difference in learning food location could be due to effects of mercury on neural processes in the hippocampus, a region of the brain related to learning and memory. These results suggest heavy metal contamination could have severe implications for songbird conservation, particularly migratory and/or food-caching species.

P3-110 BROCKMAN, TJ*; MENZE, MA; University of Louisville; *tjbroc03@louisville.edu*
Two Late Embryogenesis Abundant Proteins Do Not Protect Enzyme Activity During Desiccation in Cell Lysates
Late Embryogenesis Abundant (LEA) proteins are a class of highly hydrophilic intrinsically disordered polypeptides (IDP) that are found in many plants and some anhydrobiotic animals. Over 15 distinct LEA proteins, belonging to three different classification groups (1,3 and 6), have been found in *Artemia franciscana* and several of these proteins have been shown to be involved in the anhydrobiotic life history stage of these Branchiopods. The exact mechanisms by which specific LEA proteins protect brine shrimp embryos during desiccation is largely unknown. To gain understanding into the possible mechanisms of protection conferred by group 1 and 6 LEA proteins, enzyme assays were utilized to investigate the effect of *Af*LEA1.1 and *Afr*LEA6 on lactate dehydrogenase (LDH) activity in lysate of *Drosophila melanogaster* Kc167 cells after desiccation and rehydration. Cell lysates were utilized to probe for specific interactions between LDH and LEA proteins during water-stress in a proteome system. This may closer resemble potential interaction in the cytoplasm than observed in a binary protein study with purified enzymes and a specific LEA protein. Results show that *Af*LEA1.1 added to purified LDH protected the enzyme during desiccation and rehydration, however, when added to cell lysate, no protection of enzymatic activity was observed after rehydration compared to LEA-free control lysates. Similarly, no protection of LDH activity by *Afr*LEA6 was observed when the protein was added to cell lysates before desiccation compared to LEA-free controls. It appears likely that the protection of enzymatic activity observed by *Af*LEA1.1 in the binary protein system might be an overestimate and LDH is not a specific target of *Af*LEA1.1 under physiological conditions (supported by NSF *IOS*-1659970).

124-6 BRODBECK, MIR*; BINGMAN, VP; YUAN, S; MACDOUGALL-SHACKLETON, SA; The University of Western Ontario, Bowling Green State University; *mbrodbec@uwo.ca*
Cluster N Activity in Migrating Nocturnal Birds: Circadian Control or Facultative Regulation?
Every year, thousands of birds make long and costly trips migrating. The successful navigation that supports migration in part relies on the use of a geomagnetic compass. Cluster N, a forebrain region thought to control the geomagnetic compass, is active at night when captive night-migrating birds are exhibiting nocturnal migratory restlessness (*Zugunruhe*). However, no comparisons of Cluster N activation within the same species of a night-migrant have been made between birds exhibiting *Zugunruhe* and those not exhibiting *Zugunruhe* at night. This led us to ask: Does Cluster N activity have a circadian cycle during migration season, regardless of migration behavior, or is it more facultatively regulated on a night-to-night basis? We housed 18 white-throated sparrows (*Zonotrichia albicollis*), a night migrant with frequent stop-over periods, in outdoor aviaries. Brains were collected during the day or at night. In the night, brains were collected from birds that were exhibiting *Zugunruhe* as well as those that were inactive, as observed with IR video cameras. Thus, we had birds in three different groups: day (n=5), night migratory active (n=7), and night migratory inactive (n=6). We used immunohistochemistry to quantify immediate-early gene expression (ZENK expression) in Cluster N. Based on preliminary analyses, birds in the night migratory active group had significantly greater numbers of ZENK activation in Cluster N than those in the day, and more importantly, night migratory inactive groups. This leads us to conclude Cluster N is behaviorally regulated on a night to night basis, and given its likely control by retinal stimulation, reflects "eyes open" during nights with migration.

P3-162 BROWN, CE*; WHITEMAN, HH; DEBAN, SM; University of South Florida, Murray State University; *cbrown43@mail.usf.edu*
Within-pond Site Fidelity of Larval, Paedomorphic, and Metamorphic Arizona Tiger Salamanders, Ambystoma tigrinum nebulosum
Site fidelity has been widely reported in metamorphosed amphibians, but less is known about larvae and paedomorphic adults. Fully aquatic morphs of the Arizona tiger salamander, *Ambystoma tigrinum nebulosum*, occupy sup-alpine ponds with heterogeneous thermal profiles in the Colorado Rockies. Aquatic morphs of *A. t. nebulosum* are confined to permanent ponds; terrestrial morphs are known to move between permanent and semi-permanent ponds throughout the summer months. We studied within-pond site fidelity of PIT tagged juvenile, paedomorphic, and metamorphic Arizona tiger salamanders in five permanent and four semi-permanent ponds near the Rocky Mountain Biological Laboratory. Shallow, relatively warm regions near the perimeter of the permanent ponds, referred to as thermoregulation zones, were mapped due to apparent clustering of *A. t. nebulosum*. We found that both aquatic and terrestrial morphs of *A. t. nebulosum* do exhibit some level of site fidelity within ponds and that the distribution of differently sized animals within a pond may play a role in determining an individual's realized niche. Within-pond site fidelity does not appear to differ between males and females. Juveniles exhibit the lowest level of site fidelity, although this could be an artifact of juveniles being more easily scared from the thermoregulation zones by observers. Additional field seasons are needed to determine if within-pond site fidelity persists across active seasons and if individuals adjust their niche as size structure dynamics change over time.

113-2 BRUN, A.; BARRETT-WILT, G. A.; KARASOV, W. H.; CAVIEDES-VIDAL, E.*; CONICET-UNSL Argentina, Univ. Wisconsin-Madison; *enrique.caviedes@gmail.com*

Proteomics of the Enzyme Proteins at the Intestinal Brush Border Membrane of Vertebrates

The apical, brush border membrane (bbm) of vertebrate small intestine contains hydrolases that break down dietary polymers to monomers that are absorbed. The study of activities of the intestinal enzymes across different taxa, and of their phenotypic flexibility under different ecological scenarios, has produced general adaptive/evolutionary patterns that have received a good amount of attention. However, information on amounts of enzyme proteins at bbms is still scarce. Therefore, we explored relative abundance of intestinal enzymes in bbm, and their relationship to function, i.e. activities, in four birds, the granivorous *Taeniopygia guttata*, the granivorous/ omnivorous *Passer domesticus* and *Gallus gallus*, the insectivorous *Sturnus vulgaris* and the omnivorous *Mus musculus* and *Rattus norvegicus*. We predicted (1) that proteases and lipases would be proportionally more abundant in the insectivore, and carbohydrases proportionally more abundant in starch consumers, and (2) that the amount of enzymes in bbms would be proportional to their activities. Using intestinal tissue of four individuals of each species we prepared bbm isolates. Proteins were solubilized, digested and chromatographically separated. Peptides were analyzed by nano LC-MS/MS. MS/MS data were used to search against Uniprot and RefSeq databases. Hydrolases (i.e. their spectra) represented between 4 and 11% of the total protein (total spectra) detected. In agreement with our predictions, starlings had a higher proportion of intestinal proteases and lipases and less carbohydrases than granivorous/omnivorous species, and relative quantities of enzymes were proportional to assayed activities. Supported by NSF-IOS1354893 & CONICET-PIP0834 &UNSL2-0814.

113-6 BRUN, A; MENDEZ-ARANDA, D; MAGALLANES, M E; KARASOV, W H*; MARTÍNEZ DEL RIO, C; BALDWIN, M; CAVIEDES-VIDAL, E; Univ. of Wisc.-Madison, Max Planck Instit. for Ornithol., Seewiesen, Univ. San Luis, Argentina, Univ. of Wyoming, Laramie, Univ. San Luis, Argentina; *wkarasov@wisc.edu*

Evolution of intestinal α-glucosidases in vertebrates: Genomic and proteomic data upend previous hypotheses

Researchers have presumed that 2 distinct enzymes, orthologs of mammalian sucrase-isomaltase (SI) and maltase-glucoamylase (MGAM), are responsible for sucrasic and maltasic activities in vertebrates. Using phylogenetic analyses on genomic data and enzymatic assays, we uncovered a single ancestral α-glucosidase (AG) gene (which we here call *AAG*), homologous to the one primarily annotated as *SI* in available genomes. *AAG* appears to be widespread among vertebrates and to have given rise to additional AG genes in mammals and some birds: the enzyme called MGAM is not shared by all vertebrates, but is specific to mammals. The majority of Passeriformes (a group including almost half of all birds) appear to have only *AAG* and its product has both maltasic and sucrasic activity. The existence of many granivorous songbird species indicates that the presence of two AGs is not a necessary condition for reliance on starchy food. Proteomic and biochemical assays in isolated brush border membrane (bbm) of 3 songbirds and chickens demonstrate that songbirds express a single enzyme but chickens have a duplicated AG present in the bbm, as predicted by genomic data. Data also revealed that birds in a large songbird clade, the starlings and relatives, lack sucrasic activity because their AAG gene has undergone a functional shift, and lost sucrasic but retained maltasic activity. Our findings suggest greater diversity and different evolutionary history of bbm AGs than previously presumed, with widespread implications for our understanding of the digestive physiology of the majority of vertebrates. Supported by NSF IOS-1354893

56-4 BRUSCH, GA*; WEBSTER, T; WILSON-SAYRES, M; BLATTMAN, J; BALDWIN, A; DENARDO, DF; Arizona State University, Phoenix, AZ, Mesa Community College, Mesa, AZ; *Bruschg@gmail.com*

A Mechanistic Approach to Understanding the Relationship Between Dehydration and Enhanced Immune Function

The performance of the immune system varies with the physiological state of the organism, with immune function often suppressed during periods of negative resource balance due to scarcity or heavy investment (e.g., reproductive activity). In contrast, recent studies have shown that immune function is enhanced when water, a fundamental resource, is limited naturally or experimentally. The purpose of this study was to understand the mechanisms responsible for the peculiar finding that dehydration, while deleterious to most major physiological systems, somehow improves innate immunity in multiple species of reptile. First, we used a combination of temperature and proteinase treatments on plasma samples to explore the potential involvement of small innate peptides. Next, we looked at RNA expression in liver samples between hydrated and experimentally dehydrated animals to identify immune-related proteins that are upregulated with dehydration. Finally, we will perform western blot analyses on stored plasma aliquots to verify upregulated proteins identified by RNA-seq analysis are elevated in the blood. We found that various components of the complement and non-complement pathways are upregulated in dehydrated animals. These results provide a molecular and cellular basis for immune modulation and provide a mechanistic understanding of biochemical and proteonomic changes involved in resource-based upregulation of innate immunity. Understanding how animals cope with resource restrictions will enable us to predict how they might be impacted by future climate change, where, in many regions, rainfall events are predicted to be less reliable, resulting in more frequent drought.

P3-178 BRUSCH IV, GA*; HEULIN, B; DENARDO, DF; Arizona State University, Phoenix, AZ, University of Rennes, Paimpont, France; *Bruschg@gmail.com*

Dehydration During Egg Production Alters Egg Composition and Yolk Immune Function

Parent-offspring conflicts occur when resources are limited for allocation, and, historically, energy has been the primary currency of focus when examining these trade-offs. Water is a fundamental resource that has received far less consideration for parent-offspring conflicts. Previous research suggests that, when water is limited, reproductive females are compromised in favor of developing embryos. However, these studies limited their assessments to standard metrics such as clutch size and mass. We tested the hypothesis that the mother-offspring conflict over limited water resources leads to finer scale morphological and physiological impacts on the eggs. We predicted that water deprivation during gravidity alters female investment into her eggs, impacting egg water content and shell development. Additionally, we predicted that the yolk in these dehydrated eggs would have enhanced immune performance metrics, as has been documented in dehydrated adults. We found that eggs from water-deprived females were dehydrated as indicated by reduced percent water and greater yolk osmolality compared to eggs from females that received ad libitum water. We also found that eggs from dehydrated mothers had thinner shells and higher water loss rates. The impacts were not entirely negative as dehydrated eggs had higher antimicrobial capabilities. Also, thinner and more permeability eggshells might allow for elevated rates of rehydration from nest substrate. Overall, by examining an array of egg traits, we demonstrate that dehydration of gravid females impacts the eggs, not just the females as previously reported. As a result, the mother-offspring conflicts are indeed two-sided.

P3-116 BRYAN, A*; WILCOXEN, TE; SEITZ, J; NUZZO , JN; Millikin University, Illinois Raptor Center, Illinois Raptor Center; *abryan@millikin.edu*

Enhanced Hematological Condition in Birds of Prey Undergoing Rehabilitation is Independent of Vitamin Supplementation.

Antioxidants play a key role in protecting cells by inhibiting harmful oxidants, or free radicals, produced by metabolic processes. Antioxidants are especially important in vertebrates that are ill or are overcoming injury, such as birds of prey, that are taken into captivity for rehabilitation. In addition to the stress associated with injury, these animals incur the additional stress of being handled, which may drastically reduce their antioxidant capacity. In order to bring the raptors antioxidant levels into balance, a healthy diet is necessary. In many zoos and rehabilitation centers, the dietary supplement Vitahawk® is administered to boost Vitamin A, C, E, K, and B in captive birds. The objective of our study was to determine if Vitahawk® improves antioxidant and cardiovascular health in birds undergoing rehabilitation. Blood samples from birds were taken at admission and release to be used in a total antioxidant capacity (TAC) assay to determine differences between antioxidant capacity levels. Raptors receiving Vitahawk®. We found that non-Vitahawk® recipients had a 35% increase in antioxidant capacity from their time of admission to release, supporting that normal diet increases antioxidant capacity levels by itself. We did not find a significant difference between birds given Vitahawk® and those not given the supplement, suggesting that the supplemental vitamins and nutrients may not provide any additional benefit in a secure environment with an ample, consistent food source.

98-8 BRZEK, P*; SELEWESTRUK, P; NEDERGAARD, J; KONARZEWSKI, M; Univ. of Bialystok, Poland, Stockholm Univ., Sweden; *brzek@uwb.edu.pl*

Divergent selection for basal metabolic rate in laboratory mice affected the amount of UCP1 protein

Basal metabolic rate (BMR) quantifies the cost of body maintenance at thermoneutral zone, whereas resting metabolic rate (RMR), measured below thermoneutrality, includes also costs of thermoregulation. It is still unclear whether intra-specific variation in BMR, (i.e. in the magnitude of obligatory heat production) affects the need for extra heat production during cold stress. We studied the total amount of major thermogenic protein - UCP1 in brown adipose tissue ($_{TOT}$UCP1) in mice selected towards either high (HBMR) or low (LBMR) BMR, and acclimated to 30 °C, 23 °C and 4 °C. We showed previously that the capacity of non-shivering thermogenesis (NST) is higher in LBMR then HBMR mice acclimated to 23 °C and 4 °C. Conversely, BMR of HBMR mice is 50% higher at 30 °C, but the lines did not differ with respect to RMR at 23 °C. Here, we showed that $_{TOT}$UCP1 is higher in LBMR than HBMR mice at all temperatures, which provides molecular underpinning of the between-line difference in NST. Because this effect of selection is observed even at thermoneutral zone, we hypothesize that it reveals the presence of genetically-based, inverse correlation between BMR and the constitutive level of thermogenic capacity determined by UCP1. We attribute the between line difference in BMR at 30 °C to higher heat production of enlarged visceral organs of HBMR mice, which below thermoneutrality can be used for thermoregulation. On the other hand, lower BMR-related heat production of LBMR mice must be to a larger extend supported by NST. We discuss implications of our finding for evolution of endothermy. Financial support: National Science Centre, Poland, grant 2014/15/B/NZ8/00244 for P.B.

36-5 BRZEZINSKI, K*; MACMILLAN, HA; Carleton University; *kaylenbrzezinski@cmail.carleton.ca*

An Investigation of Cold-Induced Barrier Disruption in the Gut Epithelia of Locusta migratoria

Chill susceptible insects, like the migratory locust, often die due to an accumulation of injuries unrelated to freezing when exposed to low temperatures. These injuries, known as chilling injuries, are consistently associated with ion imbalance across the gut epithelia. It has been recently suggested that this imbalance is at least partly driven by cold-induced disruption of epithelial barrier function. Here, we aim to test this hypothesis in the migratory locust. To quantify chill tolerance, locusts were exposed to -2˚C for various durations and monitors for chill coma recovery time and survival 24h post-cold exposure. Longer exposure times significantly increased recovery time and caused injury and death. Barrier failure was tested by monitoring movement of an epithelial barrier marker (FITC-dextran) across the gut epithelia during exposure to -2˚C. There was minimal marker movement across the epithelia in the cold, suggesting that locust gut barrier function is generally conserved during chilling. We then monitored ion movement during cold exposure. Contrary to previous results, cold-induced ion imbalance still occurred. This finding may be a consequence of the large, polar, and uncharged nature of FITC-dextran, and small ions may yet leak in the cold. A similar approach was therefore undertaken to investigate gut permeability, this time using the smaller fluorescently-labelled PEG as our marker to determine if size was in fact the limiting factor in our results.

56-6 BUCHANAN, JL*; MONTOOTH, KL; BUCHANAN, JUSTIN; University of Nebraska-Lincoln; *justin.l.buchanan@gmail.com*

Metabolic costs of mounting immune responses in Drosophila

Metabolic rates reflect the overall energetic state of the organism and have been correlated with changes at the cellular level and with an organism's pace of life. Metabolic rates decrease during senescence and starvation, while energetically demanding tasks stimulate increased metabolic rates. Here I use a well-characterized mitochondrial-nuclear genotype of the fruit fly, *Drosophila melanogaster*, that has compromised aerobic energy metabolism to test for effects of compromised energy metabolism on infection and life-history traits using a natural bacterial pathogen *Providencia rettgeri*. We have previously shown that this mitochondrial-nuclear genotype compromises survival after infection with *P. rettgeri* and underlies a tradeoff between immunity and reproduction in females. Here we compare the metabolic rate during the timeframe of infection in this genotype to that of a control mitochondrial-nuclear genotype and a *Rel* mutant, which has reduced immune responses. The measurement of both O2 consumption and CO2 production during a time when immune responses should be occurring allows us to test for dynamic changes in the respiratory quotient (RQ), providing insight into the types of cellular resources being catabolized during infection.

P1-191 BUCHANAN, JL*; KERNBACH, M; GOLAS, B; JOHNSON, PLF; SWEENY, AR; WANELIK, K; BUCHANAN, JUSTIN; University of Nebraska, Lincoln, University of South Florida, Colorado State University, University of Maryland, College Park, University of Edinburgh, University of Liverpool; *justin.l.buchanan@gmail.com*

Disentangling health and fitness

A group at the IDEAS RCN workshop prior to the 2018 Ecology and Evolution of Infectious Diseases conference met to address the question "What is Health?". Impacts on host fitness are often discussed within the fields of eco-immunology, disease ecology, and life-history theory. This definition is useful when phenotypic variation in fitness can be measured. However, in species such as humans, not only can fitness not be easily measured, but health encompasses much more than fitness and should be summarized using measures that account for quality of life. Recent work by David Schneider and collaborators defines disease as a spectrum, that simultaneously captures multiple aspects of homeostasis. Here, we extend this framework by including changes in disease over the host's life span. This extension allows us to model repeat infection, immune priming, and changes due to targeted interventions (e.g., vaccines). We propose that incorporating exposure history into the reactive scope framework would provide a novel and powerful integrated framework to enhance our ability to predict how changes in individual-level homeostasis maintenance (health) can scale-up to alter population-level disease and health outcomes.

S2-7 BUDISCHAK, Sarah A.*; GRAHAM, Andrea L. ; CRESSLER, Clayton E. ; Claremont McKenna, Pitzer, and Scripps Colleges, Princeton University, University of Nebraska, Lincoln; *sbudischak@kecksci.claremont.edu*

Fueling Defense; Effects of Resources on the Evolution of Tolerance to Macroparasite Infection

Resource availability is a key environmental constraint affecting the ecology and evolution of species. Resources have strong effects on disease resistance, but they can also affect the other main parasite defense strategy, tolerance. Plant researchers and a growing number of animal disease ecologists have investigated the effects of resources on tolerance phenotypes. Surprisingly, both resource limitation and supplementation can increase tolerance in particular host-parasite systems, but a theoretical framework to understand and predict these outcomes is lacking for macroparasites. We adapted the Anderson and May macroparasite model to explore the conditions under which a tolerance strategy to parasite infection is more adaptive than resisting. Hosts must allocate a finite amount of resources among reproduction, resistance or tolerance. Across a range of resource availability, we find the evolutionary stable strategy varies with both host traits (e.g. lifespan) and parasite traits (e.g. virulence). Optimal investment in tolerance also depends upon whether parasite virulence affects mortality or fecundity, as well as the nature and cost of resistance. Our model provides a framework for interpreting previous resource-tolerance experiments and hypotheses that warrant testing in future empirical studies.

106-8 BUMP, P.*; LOWE, C. J.; Hopkins Marine Station of Stanford University. Pacific Grove, CA.; *paulbump@stanford.edu*

Insights into building complex life cycles: an investigation of development in adult and larval body plans of the indirect developing hemichordate Schizocardium californicum

There are a wide range of developmental strategies in animal phyla. For indirect-developing species, a larval body plan transforms into an adult body plan, often via a dramatic metamorphosis. In species where metamorphosis occurs by remodeling of larval tissue into adult tissue, this body plan transition provides an opportunity to investigate the cell biology of this process and how proliferation and apoptosis are balanced through this important threshold in development. We propose that *Schizocardium californicum* , an indirect developing deuterostome hemichordate worm, provides an excellent model for investigating how processes of transdifferentiation, proliferation, and cell death that remodel and reshape the larval body plan. We are using a combination of genomics, cell, and developmental biology to answer the following: given that two life phases of *Schizocardium californicum* are drastically different, how does development build the larval versus adult body plan? In our initial experiments, we investigated the spatial distribution of proliferation in both *S. californicum* larvae and adults with the aim of understanding, whether the identity or role of these proliferative cells changes through development. Our next steps involve investigating the balance of proliferation and apoptosis during the dramatic remodeling of pre-existing larval structures, along with loss and gain of larval-specific and adult-specific traits respectively.

111-6 BURFORD, BP*; WILLIAMS, R; DEMETRAS, N; HARDING, J; GILLY, WF; 1. Stanford University, Stanford, CA, 2. Southwest Fisheries Science Center, Santa Cruz, CA, 2. Southwest Fisheries Science Center, Santa Cruz, CA; *bburford@stanford.edu*

Comparable spatial organization of pelagic fish schools and squid squadrons

Many marine species form groups that exhibit schooling behavior in which conspecifics collectively perform directed movements. Squid and fish are hypothesized to have occupied similar niches over evolutionary time, and their resulting competition is reflected in convergent traits including collective social behavior. However, few quantitative measurements of schooling behavior have been made in squid, and the ability of squid to school in a manner similar to fish continues to be debated. We used cameras mounted inside a large pelagic net trawl to record the spatial organization of schools of the ecologically-similar California market squid, *Doryteuthis opalescens*, and Pacific sardine, *Sardinops sagax*. Our data suggest that schooling groups of market squid observed *in situ* exhibit similar spatial organization to those of sardine. To compare school formation in the two taxa, we examined how schooling groups reorganize after disruption by a strobe flash in a lab setting. We found that lab measurements of angular deviation for both species assessed in this manner were similar to those observed *in situ*. Despite the different types of startle-response behaviors (escape jet in squid vs. C-start in fish), groups of both species rapidly reorganized into a coherent school. As an assessment of how collective movements are coordinated in *D. opalescens* and *S. sagax*, we are currently working to compare the nature and extent to which movements of "influencers" predict movements of others within groups. Taken together, our results support the idea that groups of pelagic squid and fish exhibit convergent schooling behavior.

34-2 BURNETT, N.P.*; BADGER, M.A.; COMBES, S.A.; Univ. of California, Davis; *burnettnp@gmail.com*

Flight planning on the wing: Honeybees assess obstacle motion from afar before deciding to land on or pass through wind-blown clutter

Bees are pollinators whose habitat includes cluttered vegetation that moves when blown by unpredictable winds. Careful navigation through this habitat is important because collisions can injure bees, but little is known about how bees fly in habitats with wind-blown obstacles. We used the European honey bee, *Apis mellifera*, to test how bees navigate through habitats with wind and moving obstacles. We filmed bees flying through a 1 m tunnel with an array of horizontally oscillating vertical columns. We tested bees flying in still air, headwinds and tailwinds, and varied the frequency of the columns' oscillations. Bees either landed on or flew around the columns, and their flights could be divided into three distinct phases: an early approach (5 to 3.5 cm from the columns), a middle approach (3.5 - 2 cm away), and a final approach (2 - 0 cm away). The final flight behavior was strongly correlated with the columns' acceleration during the early approach phase: bees landed on columns that had been accelerating during the early approach and flew between columns that had been decelerating. Final flight behavior was also correlated with the columns' speed during the middle approach phase: bees landed on columns that had been moving slowly during this phase and flew between columns that had been moving rapidly. This correlation persisted over a longer portion of the middle approach if the bees were flying into a headwind. Only during the final approach did bees' flight kinematics reflect their behavioral choice: bees that landed reduced their flight speed more than bees that flew between columns. Our results suggest that bees can navigate through environments with moving obstacles by assessing obstacle motion and deciding whether to land on or fly between obstacles from afar, and then executing that decision during the final approach.

P1-14 BURNETT, N.P.*; COMBES, S.A.; Univ. of California, Davis; *burnettnp@gmail.com*

Putting interviews to the test: What biases do you face when interviewing for a post-doc?

The post-doctoral training period is a critical career stage for researchers in the life sciences. Unfortunately, many scientists from under-represented groups leave academia before entering this career stage. One potential explanation for this trend could be inequality and bias during the interview process, a process that is highly unregulated at the post-doctoral stage as compared to graduate student and faculty interviews. We designed and implemented a nationwide survey of post-doctoral researchers working in the life sciences to examine the types of interviews they experienced and to test whether interview styles were associated with demographic characteristics of the candidates. We found evidence of biases in interview formats that were linked to the sex and race of the applicant, the sex of the principal investigator (PI), and the applicants' prior relationship to the PI. These results suggest that biased interviews in the life sciences may be contributing to the under-representation of women and other minority groups at the post-doctoral and faculty career stages. Implementing a standardized interview process for all post-doctoral applicants could prevent biases and increase the representation of women and other minority groups in senior career stages of the life sciences.

61-1 BURRESS, E.D.*; WAINWRIGHT, P.C.; Univeristy of California, Davis, University of California, Davis; *edwarddburress@gmail.com*

Adaptive radiation in labrid fishes: a central role for functional novelties during 65 My of relentless diversification

Early burst patterns of diversification have become closely linked with concepts of adaptive radiation, reflecting interest in the role of ecological opportunity in modulating diversification. But, this model has not been widely explored on coral reefs, where biodiversity is exceptional, but many lineages have high dispersal capabilities and a pan-tropical distribution. We analyze adaptive radiation in labrid fishes, arguably the most ecologically dominant and diverse radiation of fishes on coral reefs. We test for early bursts of speciation, trophic diversification, evolution in a series of functional morphological traits, and the origin of 15 functional novelties associated with feeding and locomotion. We find no evidence of early burst evolution. Instead, the pace of speciation and ecological diversification has been relatively constant, while the pace of trait evolution and the origins of functional novelties has been gradually increasing toward the present. The labrid radiation seems to have occurred in response to extensive and still increasing ecological opportunity, but within a rich community of antagonists that may have prevented abrupt diversification. Labrid diversification is closely tied to a series of substantial functional novelties that individually broadened ecological diversity, ultimately allowing them to invade virtually every trophic niche held by fishes on coral reefs.

P1-267 BURROUGHS, RW; University of Chicago; *rburroughs@uchicago.edu*

Mighty Morphin' Mouse Molars: Identifying Phylogenetic and Developmental Constraints on Rodent Cheekteeth

Mammal tooth morphology and function correlate strongly with dietary ecology, and convergence is a major feature of mammalian tooth evolution. Yet, function and ecology are insufficient to explain morphological diversification and convergence within mammalian molar evolution; suggesting that development and phylogeny also limits possible structural solutions to selective pressures. Here, I use *in silico* models and empirical studies of extant and fossil rodent teeth to identify morphogenetic rules related to rodent molar morphology. Rodents are the most diverse clade of mammals extant today and their disparity in tooth morphology is substantial. Because of this, they represent an excellent potential system for investigating how genetic interactions limit morphology (e.g., morphogenetic rules). I find that lower first molars are limited to a minimum of four cusps and a maximum of nine cusps, based on both *in silico* and empirical data. Multiple developmental pathways produce the same numbers of cusps, despite highly variable cusp morphologies, thus indicating that morphospace and subsequently morphological evolution are constrained, these constraints limit cusp numbers. These constraints are both developmental and phylogenetic in nature and the identification of their role in limiting rodent molar shape provides a backdrop to allow further investigation into how tooth batteries evolved a diverse array of functions, while being fundamentally limited structurally. The framework presented here should allow for greater predictibility about shape, structure, and evolutionary outcomes of mammalian dentition even in the absence of complete organismal information.

104-7 BUSTAMANTE, J*; DANIEL, TL; University of Washington; *jorgebjr@uw.edu*

How size and shape effect abdominal contribution of insect flight control

Insect flapping flight is inherently pitch unstable and therefore demands feedback control for effective maneuverability. This feedback control is primarily governed by actuation from the wings as well as airframe deformations which drive complex flight trajectories and compensatory responses to perturbations. Such airframe deformations in flying animals assist in flight control by changing the center of mass with respect to the center of lift. However, the dependence on redirecting inertia raises an important question about the consequences of body size in motor strategies for flight control. Furthermore, these motor strategies may limit the frequencies at which airframe deformations are effective methods for flight control. To address this question of body size implications to airframe flight control mechanisms, we rely on an Euler-Lagrange formulation for multibody dynamics for a simulated moth tracking a vertically oscillating flower. The simulation was inspired by methods from model predictive control. The model was tasked with tracking a signal composed of multiple sine waves of prime number frequencies. System identification reveals the model tracks lower frequencies with greater accuracy than higher frequencies. We then explored the underlying frequency characteristics of flower tracking for more than one order of magnitude body size range. We show that smaller size scales yield the lowest error in tracking this vertically oscillating stimulus. Therefore, the moth behaves as a low-pass filter with a size dependent cut-off frequency. These results suggest a benefit to movement control for multi-body systems of this scale. Such analyses of size scale may inspire new control mechanisms for aerial robots in general.

13-7 BUTLER, JM*; ANSELMO, CM; MARUSKA, KP; Louisiana State University; *jbutl48@lsu.edu*

Female Reproductive State is Associated with Changes in Distinct Arginine Vasotocin Cell Types in the Preoptic Area of Astatotilapia burtoni

Nonapeptides play a crucial role in mediating reproduction, aggression, and parental care across taxa. In fishes, arginine vasotocin (AVT) expression is related to social and/or reproductive status in most male fishes studied to date, and is linked to territorial defense, paternal care, and courtship. Despite the plethora of studies in male fishes, it remains unknown if AVT in females varies with reproductive state and is similarly implicated in reproductive and maternal care behaviors. Using the mouthbrooding African cichlid fish *Astatotilapia burtoni*, we compared the number and size of AVT cells in the preoptic area of females of different reproductive states. Gravid and mouthbrooding females had similar numbers of parvocellular, magnocellular, and gigantocellular cells. Parvocellular cells were of similar size in gravid and brooding females, but gravid females had larger magnocellular and gigantocellular cells compared to mouthbrooding females. In addition, the size of gigantocellular cells within brooding females correlated with the number of days brooding, such that late-stage brooding females had larger AVT cells than mid-stage brooding females, suggesting a role in maternal care. To investigate this further, brains from females displaying maternal care behaviors (fry protection) will be stained for AVT and the neural activation marker, *egr1*. Together, these data indicate that AVT neurons change across the reproductive cycle in females, similar to that seen in males. These data on females complement studies in male *A. burtoni*, providing a comprehensive picture of the regulation and potential function of different AVT cell types in reproduction and social behaviors in both sexes.

P1-161 BUTLER, RM*; SOLOMON-LANE, TK; HOFMANN, HA; University of Chicago, University of Texas; *rmbutler@uchicago.edu*

The Development of Social Status in a Highly Social Fish

Social hierarchies are common and have important fitness implications. Individual phenotype strongly influences status in the hierarchy, yet little is known about how behavior and other status-relevant traits develop. We used the highly social African cichlid fish *Astatotilapia burtoni*, a model system in social neuroscience, to ask how the early-life social environment affects juvenile behavior and the establishment of status. We found that juveniles form hierarchies in a context-specific manner. In groups where individuals differed in size, status relationships formed based on size, as in adults, such that larger fish were dominant over smaller fish. If a pair of size-matched fish was present within the group, social interactions—and status relationships—were not defined by a linear hierarchy. To better understand the neuromolecular underpinnings of status, we manipulated the nonapeptide arginine vasopressin (AVP), an ancient neurohormone that regulates aggression, affiliation, and status across social vertebrates, including adult *A. burtoni*. Following intracerebroventricular injection, we observed social behavior and quantified neural expression of genes involved in the regulation of social behavior and status. Pharmacological manipulation significantly affected group social dynamics. For example, administering an AVP antagonist to one fish shifted the pattern of interactions such that the larger fish had a higher agonistic efficiency. Patterns of neural gene co-expression reveal correlations with social behavior and status, as well as the consequences of manipulating AVP on gene network dynamics. This research is critical to uncovering the neural mechanisms that underlie juvenile social behavior and status, which may have long-term consequences for adult fitness.

133-2 BUTLER, MW*; STIERHOFF, EN; CARPENETTI, JM; ADDESSO, AM; KNUTIE, SA; Lafayette College, University of Connecticut; *butlermw@lafayette.edu*

Oxidative damage increases with degree of simulated bacterial infection in tree swallow nestlings

Mounting an immune response destroys pathogens, but this response comes at a physiological cost, including the production of oxidative damage. However, many investigations into the effects of immune challenges employ a single high dose, meaning that the consequences of more mild immune challenges, which may be a better representation of naturally occurring immune challenges, are poorly resolved. We used nestling tree swallows to test how degree of immunological challenge modifies oxidative physiology and body mass, and how these metrics interact with ectoparasite load. Thus, we injected 14-day-old nestlings with either 0, 0.01, 0.1, or 1 mg lipopolysaccharide (LPS) per kg body mass, collected a blood sample 24-h later, recorded body mass, and collected nests for ectoparasite identification. From the blood sample, we quantified oxidative damage via two methodologies: TBARS, which quantifies lipid peroxidation, and d-ROMs, which quantifies derivatives of reactive oxygen metabolites. We found that nestlings injected with 1.0 mg LPS/kg body mass, which is a common dosage in ecoimmunological studies, lost significantly more body mass than individuals in other treatment groups. While treatment had no effect on TBARS, there was a dose-dependent relationship between concentration of LPS injection and d-ROMs, with higher amounts of LPS resulting in more oxidative damage. We conclude that while low-intensity immune challenges may not affect body mass maintenance, these challenges still result in detectable increases of oxidative damage. Also, nestlings subjected to blowflies and mites had higher d-ROMs values, underscoring a link between this metric of oxidative stress and immune challenges.

69-6 BUTLER, MA*; GOO, NLS; FRASER, CJ; SUNG, HW; RIVERA, JA; University of Hawaii, Arizona State University; *mbutler@hawaii.edu*

Ecomorphology of Papuan Microhylid Frogs: Performance, Hindlimb Musculature, and MicroCT Analysis

The microhylid frogs of New Guinea and its satellite islands form a large monophyletic clade of over 300 species with tremendous ecological and morphological diversity. These frogs have long been hypothesized to be part of an adaptive radiation with specializations suggested for burrowing, terrestrial, semi-aquatic, arboreal, and scansorial lifestyles. We conducted a comparative analysis of morphology, ecology, and performance with a phylogenetic context to establish the reality of the ecomorphs and an evolutionary process of adaptive radiation. We have furthermore conducted a detailed morphological analysis for a jumping and swimming specialist to understand their design features. We characterized the hindlimb musculature including the major extensors and flexors at the hip, knee, and ankle joints and modeled hindlimb forces. We analyzed skeletal morphology using microCT and found that while characteristics of the femur are highly conserved, there is clear variation in the length and shape of the tibiofibula and pelvis. We interpret these results in relation to specializations for jumping and swimming locomotor modes.

127-3 BYRON, M.L.*; BAIL, J.D.; MCHENRY, M.J.; Penn State University, University of California Irvine; *mbyron@psu.edu*

Space utilization and orientation of cydippid ctenophores in simple shear and turbulence

Most ctenophore species generate propulsion exclusively by the metachronal motion of rows of long ciliary plates (ctenes). These propulsors serve to control orientation, capture prey, perform escape maneuvers, and maintain position in the water column in spite of exposure to varying levels of turbulence and a variety of flow conditions. We were motivated to test the limits of this unique locomotor system in complex flows, both to improve our understanding of ctenophore ecology and behavior and to draw potential inspiration for new propulsion technologies at the millimeter/centimeter scale. From 3D kinematic measurements in a pseudokreisel tank, we found that the ctenophore *Pleurobrachia bachei* maintained an "upward" orientation and occupied all available space in low-shear flow, whereas animals displayed a "downward" orientation and shifted to the edges of the tank as shear increased. We also measured 2D kinematics of animals in a small speaker-driven turbulence tank, finding that animals increasingly congregated at the bottom of the tank in high turbulence. Both flows were quantified using 2D particle image velocimetry (PIV). Our results inform studies of ctenophore ecology and distribution, supporting previous findings of turbulence-avoidance behavior and quantifying ctenophore agility and maneuverability for potential future development in bioinspired vehicle applications.

P1-40 CABRERA, S*; EMLET, R; University of Florida, University of Oregon; *savannaecabrera3@ufl.edu*

Buoyancy and Swimming Behavior in Two Balanid Cyprids

For two species of barnacle cyprids, *Balanus glandula* and *B. crenatus*, potential differences in their distribution in the water column have been hypothesized to be caused by a difference in their specific gravity, swimming behavior, or a combination of both. This study sought to test these proposed explanations by measuring the sinking rates of the two species and by quantifying their location in a stable water column. To measure sinking rates, cyprids were placed in a stable water column, housed in a water jacket, and falling rates were calculated using the amount of time it took to fall two centimeters. Using a modified force-balance equation, specific gravity was calculated for the two species. To quantify the water column location, cyprids were dark-adapted for 20 seconds before being exposed to white light for a minute. After a minute, a score of 0-3 was given to each cyprid depending on where the cyprid was in a tank 24.5 cm tall. A score of 0 signified the floor, and a 3 signified the upper third of the water column. Cyprids of the two species did not differ in their specific gravity or sinking speed. Cyprids of *B. glandula* overwhelmingly preferred the top third of the water column, where as those of *B. crenatus* preferred to be in the bottom third. These results imply that cyprid distribution may be driven by behavior rather than inherent physical properties.

54-4 CAHILL, AE*; BREEN, C; CORTES, C; STANDER, R; Albion College; *acahill@albion.edu*

A salt marsh in Michigan? Characterization of invertebrates in a rare habitat type using molecular and morphological methods

Inland salt marshes are an extremely rare habitat type in North America, formed when groundwater seeps through glacial salt deposits to influence the surface community. In the midwestern United States, most salt marshes have been heavily degraded and exploited. The plant communities in one relatively intact salt marsh in Michigan have been studied, but the invertebrates are largely unknown. Preliminary work comparing this salt marsh to a freshwater marsh in Michigan showed that the salt marsh has lower richness and diversity in both sediment and water communities, as predicted given that the salt marsh is a more stressful environment. However, the patterns of these variables within the marsh (along both spatial and temporal gradients) is unknown. We used metabarcoding and traditional morphology to identify the invertebrates in the marsh. We also tested the idea that diversity and composition should change with stress by measuring the change in these variables along a transect of higher to lower salinity. Seasonal variation of physical characteristics of the marsh (e.g. water level, salinity) is also strong, and the effects of seasonal change on the composition and diversity of invertebrate communities was examined.

37-1 CAI, L*; XI, Z; AMORIM, AM; SUGUMARAN, M; REST, JS; LIU, L; DAVIS, CC; Harvard Univ., Cambridge, Universidade Estadual de Santa Cruz, Brazil, Univ. of Malaya, Malaysia, Stony Brook Univ., Stony Brook, Univ. of Georgia, Athens; *lcai@g.harvard.edu*

Thrive with Additional Sets of Genome: Widespread Paleopolyploidization Buffers plants Through Eocene Climatic Upheaval

Ancient whole genome duplications (WGDs) are important in eukaryotic genome evolution, and are especially prominent in plants. Recent genomic studies from large vascular plant clades, including ferns, gymnosperms, and angiosperms suggest that WGDs may represent a crucial mode of speciation. Moreover, numerous WGDs have been dated to events coinciding with major episodes of global and climatic upheaval, including the mass extinction at the KT boundary (~65 Ma) and during more recent intervals of global aridification in the Miocene (~10-5 Ma). These findings have led to the hypothesis that polyploidization may buffer lineages against the negative consequences of such disruptions. This work explores WGDs in the largely tropical flowering plant clade Malpighiales using a combination of newly sequenced transcriptomes and complete genomes from 42 species. We conservatively identify 22 ancient WGDs, widely distributed across Malpighiales subclades. Importantly, these events are clustered around the Eocene-Paleocene Transition (~54 Ma), during which time the planet was warmer and wetter than any period in the Cenozoic. These results establish that the Eocene Climate Optimum represents another, previously unrecognized, period of prolific WGDs in plants, and lends support to the hypothesis that polyploidization promotes adaptation and enhances plant survival during major episodes of global change. Malpighiales, in particular, may have been particularly influenced by these events given their predominance in the tropics where Eocene warming likely had profound impacts owing to the relatively tight thermal tolerances of tropical organisms.

P1-94 CAINE, PB*; EDWARDS, KM; HATCH, SA; BENOWITZ-FREDERICKS, Z M; Bucknell Univ., Inst. Seabird Research & Cons.; *pbc008@bucknell.edu*

Long- and Short-term Effects of Food Intake on Circulating Energy Substrates in Free-Living Seabird Chicks

Blood levels of energy substrates can predict mass change and are often used as indicators of overall nutrition and health in birds. However, other factors such as sex, body mass, glucocorticoid-induced energy mobilization, and dietary intake may also influence circulating substrate concentrations. As more studies seek to connect avian condition or fitness to single measurements of energy substrates, understanding the factors that generate variation in these levels in wild animals is increasingly important. To this end, we conducted two experiments on free-living black-legged kittiwake (*Rissa tridactyla*) chicks. In the first experiment, we tested the hypothesis that energy substrate levels vary in response to long term-food availability. We compared plasma triglyceride levels of chicks from nests provided with long-term food supplementation to levels of age-matched chicks from unsupplemented nests. Chicks in nests without supplementation had significantly lower triglyceride levels than chicks in supplemented nests. In the second experiment, we hypothesized that recent food consumption has a stronger effect on levels of circulating energy substrates than acute fluctuations in glucocorticoid levels. An hour before experimentally elevating corticosterone in chicks, we recorded behavior at experimental and control nests to determine the time of the most recent feeding. We evaluated the relative contributions of time since feeding and corticosterone manipulation to plasma glucose, triglycerides, and cholesterol concentrations. If recent feeding and acute corticosterone elevation affect circulating levels of these metabolites, then they may not be accurate indicators of long-term nutritional status.

P3-127 CALHOUN, AC*; SADD, BM; Illinois State University, Normal, IL; *accalh1@ilstu.edu*

The Influence of Multiple Stressors of a Fungicide and Microsporidian Parasite on Bumble Bee Health

Pollination services provided by managed and wild bees are essential for agricultural and natural ecosystems. However, threats to pollinator health leading to population declines put these services in jeopardy. Several potential causes of declines have been suggested, including exposure to pathogens and agro-chemicals. Although individual effects are widely studied, interactions between pesticides and immunity may exacerbate the negative effects of individual exposures in environments where they co-occur. In bumble bees (*Bombus spp.*), a landscape analysis demonstrated a correlation between local use of the fungicide chlorothalonil and infection loads of the microsporidian pathogen *Nosema bombi* in declining species. This is suggestive of an interaction, but causation still needs to be established. By exposing microcolonies of *B. impatiens* in a fully reciprocal design to chlorothalonil and/or *Nosema*, we test if a sublethal dose of chlorothalonil influences *N. bombi* infection and exacerbates its negative effects. We predict that chlorothalonil will reduce immune function, leading to increased infection loads and transmission potential, with associated negative effects on health. This study will be the first to experimentally assess the combined stressors of *N. bombi* and chlorothalonil in bumble bees, and will provide information on how bumble bee health will be affected by variability in agro-chemical and pathogen environments.

P1-53 CALLISON, W.E.*; HOLOWKA , N.B.; LIEBERMAN , D.E.; Harvard University; *wcallison@g.harvard.edu*

Born to Run and Breathe: Thoracic Adaptations for Ventilation in Humans and Other Cursorial Mammals

Bipedal humans, like dogs and a few other cursorial mammals, are thought to have been selected for endurance running. As to be expected, the ability to run long distances requires the ability to inspire large amounts of air for sustained periods of time. During sustained high aerobic activities, humans can be required to breathe as much as 6.1-6.9 L of air/min per kilogram of body mass, and only a few other running adapted (cursorial) mammals, including dogs, wolves, camels and horses, are capable of such sustained aerobic capacity. We experimentally test the hypothesis that humans and dogs rely on thoracic volume changes to increase tidal volume during running to a greater extent than goats, a quadrupedal, non-cursorial species. While all three species use diaphragmatic breathing to increase tidal volume in order to augment respiration with increasing oxygen demand, dogs also use increased dorsoventral expansion of the thorax, and bipedal humans use both dorsoventral and mediolateral expansions of the thorax. 3D analyses of joint morphology across four mammalian orders also show that cursorial species independently evolved more concavo-convex costovertebral joint morphologies that allow for increased rib motion and greater thoracic expansion and contraction. Evidence for similarly derived concavo-convex costovertebral joints in *Homo erectus* corresponds with other evidence for the evolution of endurance running in the genus *Homo*.

33-7 CAMARILLO, H*; TOBLER, M; Virginia Tech, Kansas State University; *camarillo@vt.edu*

Functional consequences of morphological variation between locally adapted populations

Competing selective pressures and trade-offs result in organisms evolving phenotypes that optimize overall performance, leading to local adaptation to particular environments. Selection for any one trait can result in either functional trade-offs or functional facilitation, in which multiple aspects of performance are indirectly influenced. Hence, understanding the functional repercussions of trait variation is critical to understand adaptive evolution of complex phenotypes. *Poecilia mexicana* (Poecillidae) is a live-bearing fish that inhabits toxic, hydrogen sulfide rich springs and normal freshwater streams. Fish from these two environments are exposed to divergent selection, which has resulted in phenotypic trait divergence and ecological speciation. While trait variation within and among populations has been well described, the functional implications are less clear. Using high-speed videography, we quantified different performance metrics related to variation in morphology in individual fish from sulfidic and nonsulfidic environments: burst speed swimming, steady swimming, and gill ventilation capacity. Fish from nonsulfidic habitats exhibited faster escape responses, while fish from sulfidic environments exhibited higher critical swimming speeds, exerted less effort to maintain any given swimming speed, and had higher gill ventilation capacity. We found evidence for functional trade-offs (between different modes of swimming) and facilitation (between steady swimming and gill ventilation). Overall, performance differences matched predictions based on environmental conditions in each habitat type, with hypoxia and energy-limitation in sulfidic and higher levels of predation in non-sulfidic habitats.

84-7 CAMBRON, LD*; YOCUM, G; GREENLEE, KJ; North Dakota State University, Fargo, USDA-ARS, Fargo, ND , North Dakota State University, USDA-ARS, Fargo; *liz.cambron@ndus.edu*

What's going on during diapause? Investigating the insulin pathway in overwintering Megachile rotundata

Many insects go through diapause, a stage similar to hibernation, to survive winter months. During these months, insulin signaling decreases, but the importance of this pathway in overall diapause regulation is unclear. Few studies have investigated the role of insulin signaling in diapause, and further studies are needed to understand the biochemical and physiological changes that take place during diapause. Our previous studies showed that when exposed to fluctuating temperatures during diapause, alfalfa leafcutting bees, *Megachile rotundata*, have increased survival. Our hypothesis is that during the high temperature period, insulin signaling and oxidative stress repair mechanisms are able to function, leading to increased survival. To test this hypothesis, *M. rotundata* were overwintered in either a lab setting at a constant 4˚C or in the field in naturally fluctuating temperatures. Expression of target genes in the insulin signaling pathway was measured using quantitative PCR. Our prediction was that bees reared in the field would have higher expression of target genes throughout overwintering compared to bees reared in the lab at constant low temperatures. Gene expression data was analyzed with qbase+ software and normalized to expression of three reference genes. Our results showed a trend supporting our hypothesis, with bees overwintered in the field having higher expression than bees overwintered in the lab. Further analysis will be done to verify the significance of these trends. Currently farmers are unable to assess the health of overwintering *M. rotundata*, leading to high mortality rates from improper storage conditions. By understanding how the insulin signaling pathway changes in overwintering bees, genes from this pathway could be used as biomarkers for healthy bees.

P1-51 CAMP, AL*; OLSEN, AM; HERNANDEZ, LP; BRAINERD, EL; University of Liverpool, Brown University, George Washington University; *Ariel.Camp@liverpool.ac.uk*

Ventral body muscles power suction feeding in channel catfish

Many ray-finned fishes use their large body muscles to help power mouth cavity expansion during suction feeding. The dorsal (epaxial) body muscles can power expansion by shortening to elevate the cranium, and the ventral (hypaxial) body muscles by shortening to retract the pectoral girdle. While epaxial-powered cranial elevation has received much more study, in some species (including catfishes) it appears to be absent. Can these fish generate powerful suction expansion with the hypaxials alone, or are they limited to low-power feeding or a greater reliance on cranial muscle power? We measured 3D skeletal kinematics and axial muscle shortening using X-ray Reconstruction of Moving Morphology (XROMM) and fluoromicrometry, respectively, during suction feeding in channel catfish. The rate of mouth volume expansion was calculated from the XROMM animations using a dynamic digital endocast, and combined with intraoral pressure recordings to estimate suction expansion power. Catfish generated powerful strikes (10-12 W, similar to peak powers of largemouth bass and bluegill sunfish), without epaxial power. During suction expansion, the epaxials shortened minimally, and the cranium elevated less than 5 degrees relative to the body. The hypaxials shortened substantially (10% strain) to retract the pectoral girdle by about 12 degrees relative to the body. Some cranial muscles also shortened, but were too small to contribute meaningful power to mouth expansion. The hypaxials alone were capable of powering these strikes without exceeding 90 W/kg, a relatively low power output. Thus, powerful suction feeding doesn't require epaxial-powered cranial elevation, and the contribution of dorsal and ventral body muscles to suction power clearly varies across fishes.

11-3 CAMP, AL; University of Liverpool; *Ariel.Camp@liverpool.ac.uk*

What fish can teach us about the feeding functions of postcranial muscles and joints

Studies of vertebrate feeding have, quite reasonably, focused on the bones and muscles of the head, not the body. Yet, postcranial structures like the spine and pectoral girdle are anatomically linked to the head, so there may also be mechanical connections through which these musculoskeletal systems contribute to feeding. The role of postcranial structures during feeding has been best studied in ray-finned fishes, where the body muscles attach directly to the head and actively shorten to expand the mouth. Therefore, I used the anatomy and motion of the head-body interface in fishes to develop a mechanical framework for studying postcranial functions during feeding. In fish the head and body are linked by the vertebral column, the pectoral girdle, and the body muscles that actuate these skeletal systems. The joints and muscles of the cranio-vertebral and pectoral interfaces may have distinct morphologies, which in turn determine the mobility of the head relative to the body. The postcranial interfaces can function as anchors during feeding: the body muscles and joints minimize motion between the head and body to stabilize the head, or transmit forces from the body. Alternatively, the postcranial interfaces can be motors: body muscles actuate motion between the head and body to generate power for feeding motions. The motor function is likely important for many suction-feeding fishes, while the anchor function may be key for bite- or ram-feeding fishes. This framework can be used to examine the role of the postcranial interface in other vertebrate groups, and that role changes (or not) with morphology and feeding behaviors. Such studies can expand our understanding of muscle function, as well as the evolution of vertebrate feeding behaviors across major transitions such as the invasion of land and the emergence of jaws.

P1-123 CAMPBELL, NA*; BOWDEN, RM; CASTO, JM; PAITZ, RT; Illinois St U; *nacamp2@ilstu.edu*

Deciphering the consequences of yolk testosterone metabolism in birds: Inactivation or modification of an active signal?

Maternal steroids transferred to eggs produce variable phenotypic effects in offspring. One maternal steroid that has garnered interest is testosterone due to its ability to elicit permanent, organizational effects in the brain and other tissues; however, vertebrate embryos actively regulate their maternal steroid exposure through steroid metabolism. We previously showed that in European starling (*Sturnus vulgaris*) eggs, testosterone is metabolized to etiocholanolone early in development which leads us to ask: When does this testosterone metabolism begin? And is etiocholanolone capable of influencing early growth of the developing embryo and extraembryonic membranes? To address the first question, 20 eggs were injected with tritiated testosterone (3H-T) and incubated for 0, 4, 8, and 12 hours to track the movement of testosterone early in development. To address the second question, 130 eggs were injected with either high (2.0 ng/egg), medium (1.0 ng/egg), or low (0.5 ng/egg) doses of etiocholanolone and sampled on days 3 and 5 of development to quantify the mass of the embryo and extraembryonic membranes. The conversion of testosterone to etiocholanolone was observed after only 4 hours of development. However, etiocholanolone manipulation had no significant effect on the growth rate of the embryos or extraembryonic membranes. This finding suggests that the conversion of yolk testosterone to etiocholanolone may be an inactivation pathway that buffers the embryo from the effects of maternal steroids.

S4-1 CAMPBELL, RA*; DEAN, MN; Okinawa Institute of Science and Technology, Max Planck Institute for Colloids and Interfaces; *robert.campbell@oist.jp*

Adaptation and Evolution of Biological Materials

Biological materials, whether inside or outside an organism, play a vital role in survival and mediation of interactions with the environment. Although the characterization of biomaterials performance has leapt forward in the past decades, our understanding of how performance varies and is shaped across ecology or evolutionary history lags behind. Is performance at a material level selected for in evolution? How do abiotic factors limit and enhance function? How do materials respond, adapt, and evolve with environment and organism? This talk will provide an introduction to these questions, which will then be addressed further throughout the day by the speakers in symposium S4, "Adaptation and Evolution of Biological Materials." The session will cover a range of organisms and organizational scales, from skeletal form-function evolution to material-mediated vibration sensing, structural color, and plant and animal anchoring tools. Our introduction highlights the intention behind that diversity, as we showcase the common opportunities that modern materials approaches provide for integrative studies of organismal adaptation and evolution.

P2-209 CAMPBELL, RA*; MIKHEYEV, AS; Okinawa Institute of Science and Technology; *robert.campbell@oist.jp*

3D Silk Gland Geometries for Comparative Spider Biology and Bio-inspired Material Processing

Spider silk is a diverse category of materials produced under different mechanical conditions. In orb-weaving spiders, up to six types of silk are produced by a combination of secretions from up to eight distinct silk glands. The "glandular affiliation hypothesis" indicates that discrete silk materials are produced and assembled in each gland. However, the time consuming nature of histology has largely limited the study of spider silk materials to external spigot and spinneret morphology on one hand, and silk proteomics and its genetic origins on the other. Information on internal gland morphology is necessary for understanding how fluid flow conditions combine with protein sequence variation and protein chemistry to produce different silk material properties. To date, only a few studies exist on the mechanical flow conditions responsible for protein assembly, and only one gland geometry from one spider species has been used to model fluid flow during spinning, the large major ampullate gland of *Nephila edulis*. Here we show that microCT can be used to rapidly isolate 3D silk gland geometries of multiple gland types. Such data enables the study of 3D comparative gland morphology across spider taxa. We propose the integration of comparative gland morphology into new studies of spider silk evolution. One exciting feature of the data is that it can also be exported for use in computational simulations of fluid flow and molecular assembly, potentially informing the development of bio-inspired material fabrication techniques as well as the study of fundamental biological questions.

P1-226 CAMPOS, CI*; MARTINEZ, MA; RUSSELLO, MA; WRIGHT, TF; New Mexico State University, University of British Colombia, Okanagan; *campos73@nmsu.edu*

Genetic Structure and Diversity in Wild and Captive Populations of the Critically Endangered Blue-Throated Macaw (Ara glaucogularis)

A key aspect in the conservation of endangered populations is understanding their underlying genetic structure. The blue-throated macaw is endemic to Bolivia and is one of the most endangered species of macaw, with an estimated 250 birds remaining in the wild. Like many parrots, the blue-throated macaw has sizeable populations in zoos and private ownership. This raises interesting questions about the genetic diversity within, and the genetic relatedness between wild and captive populations. Our goal is to assess genetic variation in wild and captive populations to inform conservation efforts for this highly endangered species. We genotyped 66 wild individuals from Bolivia and 54 captive individuals from the US, Canada and Bolivia at 12 polymorphic microsatellite loci to determine genetic diversity and relatedness. We examined population structure using a Bayesian clustering approach and calculated population F statistics to determine the extent of population structure. Our results using STRUCTURE show that wild Bolivian populations are genetically distinct from captive populations; this result was echoed by a significant pairwise Fst value of 0.059 between the two populations. Ongoing analyses will test for the presence of population bottlenecks and inbreeding in both captive and wild populations. These results will help inform ongoing efforts to manage wild populations and augment them with the release of captive-bred individuals.

61-3 CANNON, JT*; ROBERTS, NG; EGAN, J; HONG, C; PICCIANI, N; EERNISSE, DJ; OAKLEY, TJ; UC Santa Barbara, California State University Fullerton; *joie.cannon@gmail.com*

A lens to the past: timing of lens eye origins

Eye evolution is a classic system for studying origins of morphological complexity. Eyes with lenses that focus light onto photoreceptor cells have evolved at least 11 times in metazoans. Although many of these lens eyes have Cambrian origins, some, such as the unique aragonite lens of polyplacophoran molluscs, may have evolved as recently the Eocene. Here, we address the question of when in evolutionary time these independent origins occurred. In the case of vertebrates, arthropods, cephalopods, bivalves, and gastropods, we estimated an age range based on published data. We evaluated evidence for homology of lens eyes within each lineage to correct for the possibility of multiple origins. Using published phylogenies and fossil-calibrated time trees, we determined a maximum (age of MRCA without eyes) and minimum age of origin (age of crown group with lens eyes). In some cases, as in Cubozoa, we estimated time trees using multilocus datasets compiled from NCBI and fossil calibrations. Our preliminary estimates of eight lens eyes indicate that these structures evolved in the Precambrian, Cambrian, or as recently as the late Devonian. Some taxa present unique challenges due to the paucity of their fossil records (i.e. Nemertea), the variable nature of their photoreceptor structures (i.e. sabellid polychaetes) or the absence of robust phylogenetic hypotheses (i.e. Polyplacophora). These three lineages are candidates for the most recent independent origin of a metazoan lens eye. To estimate the age of origin of chiton aragonite lens eyes, we are using target-capture phylogenomic methods to generate a time-calibrated phylogeny. Together, our timeline of lens eye origins will provide a valuable temporal context forfurther comparative research on evolution of complex structures.

P1-138 CANTU, I; GABOR, C*; Texas State University; *inc9@txstate.edu*

Effects of Acute and Chronic Predator Stress on Mating and Stress Hormones in Mosquitofish

Predators directly affect populations through mortality and indirectly through altered behavior and physiological stress response. Physiological and behavioral response may vary depending on whether the threat is perceived as an acute or a chronic stressor. Acute stress from predators can enhance reproductive success. In contrast, chronic exposure to predators can negatively affect reproductive success. Cortisol is the main stress hormone in fish and increases in response to predation threat and may facilitate antipredator behavioral response. We tested the hypothesis that chronic and acute predation threat would affect mating behavior of the livebearing mosquitofish, *Gambusia affinis*. We exposed mosquitofish (n=10-15/treatment) to Green sunfish, *Lypomis cyanellus*, a major predator for either 7 days or 30 min. We set up half of a tank with one male separated by a clear divider from two mature females (large and smaller).We placed the sunfish in the other half of the tank (clear divider) if the treatment was chronic exposure. On day 7, we placed the sunfish on the other half of the tank for the acute treatment for 15 min. In the presence of the predator, we removed the divider separating the male and females and recorded the number of mating attempts (gonopodial thrusts) towards each size of female for 15 min. We also examined mate choice using the same set-up but with no predator. Males thrusted significantly more towards the larger female over smaller females across all treatments. Interestingly males in the acute stress treatment, mated significantly more than males in the chronic or control treatments (which did not differ from each other). These results indicate that acute stressors increase mating behavior and that fish may have habituated to the threat of predators in the chronic treatment.

P3-184 CAOILI, EC*; QUIROGA-ARTIGAS, G; SCHNITZLER, CE; Whitney Lab for Marine Bioscience, University of Florida; *e.carter@whitney.ufl.edu*

Determining the Expression Patterns of Two Brachyury Paralogs in Hydractinia Head Regeneration

The gene *Brachyury* belongs to the T-box family of transcription factors and is a target of the canonical *Wnt* signaling pathway. First discovered in mouse, this gene is widely known for its conserved role in mesoderm formation and body axis patterning across bilaterian species. Despite its established function as a mesodermal marker, homologs of *Brachyury* have recently been discovered in diploblasts, including two paralogs (*HyBra1* and *HyBra2*) in the freshwater cnidarian *Hydra magnipapillata* (Bielen et al., 2007). RNAseq data from our lab and collaborators indicated that two paralogous *Brachyury* genes are also expressed in the colonial hydrozoan, *Hydractinia echinata*. Moreover, both of these genes are highly upregulated in blastema tissue during head regeneration at 24 hours post head removal. We plan to compare spatial and temporal expression patterns of both *Brachyury* paralogs using in situ hybridization and qPCR at different time points during head regeneration in our lab's model organism, *Hydractinia symbiolongicarpus*. Defining the expression patterns of these *Brachyury* genes during regeneration and in intact adult polyps will serve as an informative first step in investigating the role of this conserved gene in *Hydractinia*. We will compare our results to recent expression studies of *Brachyury* genes in other model cnidarians.

71-2 CAPSHAW, G*; SOARES, D; CARR, CE; Univ. of Maryland, College Park, New Jersey Institute of Technology; *gcapshaw@umd.edu*

Extratympanic auditory sensitivity to sound and vibration in lungless salamanders

How does an animal perceive sound without ears? The tympanic middle ear is a key sensory innovation that emerged several times in vertebrate evolutionary history as early tetrapods transitioned from aquatic to terrestrial lifestyles. This structure is typically comprised of a tympanic membrane connected to the oval window of the inner ear via one to three ossicles in an air-filled middle ear cavity, and it functions as a transducer of airborne sound pressure into fluid movement in the inner ear. However, several terrestrial vertebrate species including "earless" frogs, snakes, and salamanders have lost their tympanum and middle ear cavity. We used salamanders as a model to test the role of several proposed extratympanic pathways for sound and vibration detection including bone conduction, the amphibian opercularis system, and the air-filled lungs. We compared auditory sensitivity in lungless salamander species against those that retain lungs, and found that lungs are not necessary for terrestrial hearing in atympanic species. Bone conduction is sufficient for detection of low frequency sound and vibration.

26-8 CARBECK, KM; DEMORANVILLE, KJ; D'AMELIO, PB; GOYMANN, W; TROST, L; PIERCE, BJ*; BRYLA, A; DZIALO, M; BAUCHINGER, U; MCWILLIAMS, SR; Canisius College, Buffalo, Univ. of Rhode Island, Kingston, Max Planck Inst. for Ornithology, Seewiesen, Max Planck Inst. for Ornithology, Seewiesen, Sacred Heart Univ., Fairfield, Jagiellonian Univ., Krakow; *pierceb@sacredheart.edu*

Environmental cues and dietary antioxidants affect breeding behavior and testosterone of male European Starlings (Sturnus vulgaris)

Environmental cues, such as photoperiod, regulate the timing of major life-history events like breeding through direct neuroendocrine control. Less known is how supplementary environmental cues (e.g., nest sites, food availability) interact to influence key hormones and behaviors involved in reproduction, specifically in migratory species with gonadal recrudescence largely occurring at breeding sites. We investigated the behavioral and physiological responses of male European starlings to the sequential addition of nest boxes and nesting material, green herbs, and female conspecifics and how these responses depend on the availability of certain dietary antioxidants (anthocyanins). As expected, cloacal protuberance volume and plasma testosterone of males generally increased with photoperiod. More notably, testosterone levels peaked in males fed the high antioxidant diet when both nest box and herbal cues were present, while males fed the low antioxidant diet showed no or only a muted testosterone response to the sequential addition of these environmental cues. Males fed the high antioxidant diet maintained a constant frequency of breeding behaviors over time, whereas those fed the low antioxidant diet decreased breeding behaviors as environmental cues were sequentially added. Our results highlight the importance of supplementary environmental cues and key resources such as dietary antioxidants in enhancing breeding condition of males, which conceivably aid in attraction of high quality females and reproductive success.

P2-270 CARLSON, BM*; HURTIG, JE; SZALAY, TE; MULLIN, MM; The College of Wooster; *bcarlson@wooster.edu*

That's a Fish of a Different Color: Using a Candidate Gene Approach to Investigate Color Variation in Betta splendens

Betta splendens, commonly known as the Siamese fighting fish, is a species widely known to the public, but comparatively poorly known to the scientific community, especially from a genetic standpoint. However, these fish are tractable in a lab setting, have a dedicated hobbyist community actively engaged in citizen science, and show excellent potential for use in scientific outreach to a wide variety of audiences, making them an extremely attractive study system. Notably, *Betta splendens* displays vibrant pigmentation in its natural state, but artificial selection has resulted in captive-bred populations showing a wide variety of pigmentation phenotypes that vary in both coloration and patterning. While hobbyists and pet owners prize these fish for their beauty, these derived pigmentation phenotypes are also of scientific interest. Past studies have shown that these changes are not merely aesthetic, but rather that they impact behavior (e.g., mate choice and schooling) and physiology (e.g., immune responses) as well. Despite the attention that this subject has received, the specific genes mediating these changes in pigmentation have yet to be identified. Here, we investigate of the genetics underlying several *Betta splendens* pigmentation phenotypes, picking up where the citizen scientists of the hobbyist community have left off. Using a candidate gene approach, we have newly sequenced large portions of several relevant genes and identified variation in both coding sequences and gene expression. This work, together with our ongoing efforts, promises to shed light on the genetic underpinnings of the widely varied pigmentation phenotypes observed in this species.

67-5 CARNEY, RM; University of South Florida; *ryanmcarney@gmail.com*

Evolution of the Archosaurian Shoulder Joint and the Flight Stroke of Archaeopteryx

Archosaurs are a remarkable group of animals that exhibit a diverse locomotor repertoire at the shoulder (glenohumeral) joint, from quadrupedal alligators and dinosaurs to flying pterosaurs and birds. The origin of avian flight, despite a multitude of exciting new fossils, remains both controversial and inextricably linked to *Archaeopteryx*. Here I address this question through an integration of theoretical, anatomical, experimental, and comparative approaches. First, I established a standardized, joint-based approach for analyzing skeletal anatomy and motion (kinematics), which served as a comparative framework throughout. A high-resolution 3D reconstruction of *Archaeopteryx* was then created via multiplanar X-ray microtomosynthesis of the Thermopolis specimen (WDC-CSG-100). Results provide resolution to controversial aspects of *Archaeopteryx* anatomy that are critical for assessing flying ability, such as the orientations and articulations of the scapula, glenoid, and wing. Next, in order to inform and constrain the reconstruction using extant phylogenetic bracketing, I investigated the *in vivo* glenohumeral kinematics of walking alligators and flapping chukars, recorded via marker-based X-ray Reconstruction of Moving Morphology. Results confirm the hypothesis that the glenohumeral motions of these disparate archosaurs are fundamentally similar, despite moving against very different media. The joint-based approach also provided a framework for "scientific motion transfer." This tested whether the *in vivo* motions are consistent with the range of motion in *Archaeopteryx*, and provided empirical, phylogenetic constraints for reconstructing motion. Findings reveal that the *Archaeopteryx* glenoid permits most humeral excursions from both extant archosaurs, and also indicates a more avian motion path. Ultimately, these anatomical and experimental lines of evidence demonstrate that *Archaeopteryx* was kinematically capable of active flight.

P3-168 CARPENETTI, JM*; STIERHOFF, EN; DIAMANTIDES, LC; WALLACE, JW; BUTLER, MW; Lafayette College, Easton, PA; *carpenej@lafayette.edu*

Survival of house sparrows seems to decrease only in response to high-intensity immune challenges

Immune challenges can have large consequences on animals, such as decreased survival, which could be due to intensity. However, some survival-based costs may not show until later in life. To test if degree of immune challenge was related to survival, we issued one of four different doses of an immune challenge to nestling house sparrows and quantified survival during the nestling and fledgling periods. We injected a saline solution of lipopolysaccharide (LPS), a bacterially derived molecule that stimulates vertebrate immune systems, in doses of 0.0, 0.01, 0.1, or 1.0 mg LPS/kg body mass to nearly 150 10-day-old house sparrows during the summer of 2018. We also attached unique radio frequency identification (RFID) tags to each nestling. For nestling survival, we checked nests daily for mortality or fledging. For post-fledging survival, we placed antennae on bird feeders to detect RFID tags, showing which birds were still alive post-fledging. We predicted that as immune challenge intensity increased, survival would decrease. While the intensity did not seem to affect nestling survival, we detected fewer fledglings that received 1.0 mg LPS/kg body mass during the fledgling period. We cannot explain this, but possibly the energy invested in the immune response compromised the bird's nutrient stores, increasing the chance of starvation post-fledging. The other doses did not show a survival difference, so we can infer that they did not have lasting effects. The trend manifested only at the highest dose, suggesting that less intense (and putatively common in nature) immune challenges may not have the same effects on survival.

P3-53 CARR, JA*; SULLIVAN, CM; TYTELL, ED; Salem State University, Emmanuel College, Tufts University; *carr.je@gmail.com*

Twitch Kinetics on the Descending Limb of the Length-Tension Curve of Skeletal Muscle.

Muscle intrinsically produces different amounts of force depending on its length and its velocity. These force-length and force-velocity relationships are often discussed when developing models of muscle function. My research examines a previously unsteady force-length relationship: how length affects the speed at which force develops. I measured a standard force-length curve in isolated muscle preparations from the silver lamprey, starting at the ascending limb, proceeding through optimal length, and down the descending limb to the point where peak muscle force was negligible. At each length, I stimulated the muscle to produce a twitch. From each of the twitches, the force produced by the muscle and the timing of various points relative to the stimulus was measured. During force development, the timing and force were measured at 50%, 90% and 100% maximal force. During force decay, the force and timing were measured at 50% and 90% relaxation. From these data, the rate of force development and decay was calculated at different portions of the twitch. Previous results show that on the ascending limb and the plateau region that the rate of force development increases as length increases and the rate muscle relaxation decreases with as length increases. We are currently extending these measurements onto the descending limb of the force-length curve, to determine whether this effect is due to myosin-actin overlap or some other biochemical effect such as titin winding. We hypothesize that if the changes in twitch kinetics are due to myosin-actin overlap, which increases on the ascending limb, then the rate of force development and the rate of muscle relaxation will decrease on the descending limb of the length tension curve as there is less and less myosin-actin overlap.

P2-127 CARRIER, TJ*; REITZEL, AM; Univ. North Carolina, Charlotte; *tcarrie1@uncc.edu*

Ecological Masking Of Animal-Associated Bacterial Communities

Morphological plasticity is a genotype-by-environment interaction that enables organisms to increase fitness across varying environments. When faced environmental heterogeneity, an animal holobiont may acclimate by shifting the composition of the associated bacterial community. By inducing morphological plasticity in three confamilial sea urchins, we test the hypothesis that the bacterial community co-varies with the expression and magnitude of plasticity. While each urchin has a species-specific bacterial community, the expression of plasticity resulted in the convergence on a phenotype-specific bacterial community, with community shifts being proportional to the expression of the trait. Moreover, associating with a phenotype-specific bacterial community was independent of ecological drift, diet quality, and developmental stage, even though the bacterial communities established by the eggs change gradually during embryonic and larval development. Animal-associated bacterial communities are also taxonomically distinct across host biogeography. Using larvae of the echinoid Strongylocentrotus droebachiensis from coastal locations in the Pacific and Atlantic Oceans, we test the hypothesis that host geographical origin better correlates with community composition than does local variation (e.g., diet and phenotype). Our comparisons of the bacterial communities associated with S. droebachiensis larvae suggest that geographic location better correlates with community composition than local biological (e.g., phenotype) and ecological (e.g., diet quantity) variation. Taken together, these results suggest that echinoid larvae associate with a phenotype-specific microbial community that is specific to but can be masked ecologically by host biogeography, implying that scaling and the potential for ecological masking should be considered when studying host-microbiome dynamics across an ecological landscape.

P3-65 CARRIER, DR*; BOYNTON, AM; Univ. Utah, Salt Lake City; *carrier@biology.utah.edu*

Is the Neck Part of the Human Core?

The musculoskeletal core provides a stable base that allows limbs to exert forces on the environment. We hypothesized that the human core is actually a musculoskeletal loop that begins at the pelvis on one side of the body and extends cranially, via active muscles, to the skull and then extends caudally down the opposite of the neck and trunk. To test whether or not the neck is part of the core we used surface electrodes to measure the activity of a set of cervical and trunk muscles during maximum effort counter-movement jumps. To determine whether cervical muscle activity during jumps function to control posture of the head and/or function to assist in stabilization of the trunk against the moments applied to the pelvis by the leg retractor muscles we compared muscle activity during control jumps to jumps in which we (1) increased the mass of the head by 20%, and (2) reduced peak accelerations by approximately 10% by pulling downward on the subject's hips with elastic tethers. When subjects jumped with mass added to their heads, changes in muscle activity varied from subject to subject and no consistent pattern was observed. When subjects jumped with increased vertical force, to reduce acceleration, activity increased significantly in both the strap (i.e., sternohyoid and sternocleidomastoid) and epaxial (i.e., semispinalis) muscles. These results do not support the hypothesis that the superficial muscles of the neck (i.e., those accessible with surface electrodes) play an important role in postural support of the head during active movement. Instead, our results suggest that these cervical muscles contribute to core stability in response to moments imposed on the pelvis by the extrinsic muscles of the leg. These results have implications to the locomotor function of the tetrapod neck and to the prevention of spinal injury.

76-6 CARRINGTON, E; University of Washington; *ecarring@uw.edu*

Environmental Safety Factor: a framework for evaluating physiological performance in an ecological context

The central aim of ecological biomechanics is to understand linkages between organismal form and function in natural environments, a goal that is of increasing importance in the context of changing climates. Historically, comparative biomechanists have excelled at quantifying morphology, structure and physiological performance in controlled laboratory settings. Mimi Koehl, however, was an early and frequent proponent of the importance of measuring the environment at the spatial and temporal scale of the organism. An especially useful concept Koehl and colleagues have championed is the Environmental Safety Factor (ESF, aka Environmental Stress Factor), which describes the strength of an organisms relative to the forces it experiences in the field. I will review some of the biological systems where this approach has been used successfully (e.g., flow forces encountered by sea anemones and kelp), and how it can be extended beyond biomechanics to other aspects of physiological performance. I will highlight some recent technological advances in measuring biomechanical performance in nature and some of the novel insights that have resulted.

P3-123 CARSON, KMH*; RASHID, SB; LAWSON, ER; MOSS, AG; Auburn University, Alabama, Auburn University, Alabama , University of Georgia, Athens, Auburn University ; *kmh0100@auburn.edu*

Purification and identification of an exceptionally resilient orange fluorescent protein from a novel species of anemone, a variant of the Gulf anemone Calliactis tricolor

GFP was one of the most useful discoveries of the 20th Century, due to its subsequent use in cell and molecular tagging applications, resulting in three Nobel Prizes in 2008 (Noble Media AB 2014). GFP and similar proteins, including anthozoan fluorescent proteins, have been used in numerous research efforts to probe cellular structure and function since its introduction. We have discovered a similar protein in a variant of the common anemone, *Calliactis tricolor*, from the Alabama Gulf Coast, which, unlike other anthozoan fluorescent proteins (Curr. Opin. Chem. Biol. 20:92; Curr. Opin. Biol. 12:505), is extraordinarily long-lived and resilient. The anemone's mouth and mesenteries produce intense orange fluorescence, peak emission at 510 nm and 570 nm when illuminated by blue light at 500 nm and 540 nm. The protein appears to be freely associated with the cytoplasmic space of mesentery cells; purification of the protein yields a ~10S trimeric quaternary complex with three bands at 31, 25 and 10 kDa as revealed by SDS-PAGE. LC-MS/MS reveals that the fluorescence moiety is novel and has effectively no homology to any previously known fluorescent protein; moreover the fluorescent group is found only in the largest subunit. Ongoing whole genome analysis and differential transcriptomic analyses seek to reveal genome organization and appropriate regulatory elements and should provide data for future incorporation of this group into cellular probes. Our work reveals that this is a very easy to purify, resilient and easily handled protein and a look into genome organization and identification. Funds: Internal Grants Program, OVPR, Auburn Univ.

S10-3 CARTER, AW*; PAITZ, RT; BOWDEN, RM; U Tennessee, Illinois St U; *acarte82@utk.edu*

The devil is in the details: natural variation in maternal estrogens and temperature are key to understanding TSD

Our understanding of biological processes is often based on studies using simplified treatments, like constant temperatures, but incorporating a higher degree of realism in treatment design is crucial to deciphering how biological processes operate in nature. This need is exemplified by ongoing research in temperature-dependent sex determination (TSD), where there is a disconnect between sex ratios produced in the lab and the field. Specifically, lab incubation studies using constant temperatures or consistent diurnal fluctuations do not explain how females are produced under cool field temperatures. We explored how exposing embryos to varying durations of increased temperatures (e.g. heat waves) affect sex determination in *Trachemys scripta* to help resolve this disparity. Embryos are exceedingly sensitive to heat waves; a 50:50 sex ratio is produced in as few as ~8 heat-wave days (at 29.5 ± 3°C). Surprisingly, if baseline temperatures are dropped from 27± 3°C to 25 ± 3°C, the heat wave duration needed to trigger a 50:50 sex ratio changes minimally (~9.5 days), suggesting that sex determination occurs over relatively few days during incubation and that temperatures outside of this period minimally impact sex determination. We also found that the exposure duration required to trigger ovary development is affected by endogenous concentrations of maternally derived estrogens; late season clutches with higher estradiol concentrations require shorter exposure durations than early season clutches. By integrating natural thermal variation during incubation with maternal estrogens, our data help resolve how sex determination occurs in the field, and more broadly underscore the importance of considering relevant environmental variation in the study of eco-physiology.

98-6 CARTER, W.A.*; DEMORANVILLE, K.J.; PIERCE, B.J.; MCWILLIAMS, S.R.; University of Rhode Island, Sacred Heart University; *wales_carter@uri.edu*

Seasonal progression and diet fatty acid composition influence metabolic rates, sustained exercise performance, and oxidative enzyme activity in European Starlings

Diet quality, in addition to quantity, is an often-overlooked factor that can influence the performance and success of animals. In particular, diet fatty acid composition has been related to metabolic performance in a wide range of taxa. However, the continuity of these effects over different measures of performance, interactions with seasonal changes in life-history stages, and the role of specific fatty acids remain relatively unknown. We tested the effect of dietary linoleic acid (LA) on basal and peak metabolic rates, flight duration, energy expenditure, and rates of fat and lean catabolism during a voluntary wind-tunnel flight, and the activity of the metabolic enzymes CPT, HOAD, CS, and LDH over the course of a simulated fall migratory period in European Starlings. We found a consistent interaction between diet and season influencing metabolic rates and long-flight performance, with birds fed high-LA diets decreasing in metabolic rates and rates of energy expenditure and fat catabolism over the course of the fall season and low-LA birds increasing in those measures. Enzyme activity did not display this interaction, but did increase over the season for CPT, HOAD, and LDH. CPT activity was positively related to flight duration and rate of fat catabolism. These results indicate that the influence of dietary LA on metabolic performance is contingent on seasonal progression and that changes in whole-animal performance are likely mediated by tissue-level changes in metabolic enzyme activity and density.

P1-70 CARTER, M*; HOGAN, AVC; BALANOFF, AM; BEVER, GS; Johns Hopkins University School of Medicine, Baltimore; *mcarte61@jhu.edu*

Functional Correlates of Floccular Size in Pan-Aves

The avian vestibulocerebellum coordinates incoming vestibular information with movements of the head and eyes. It is a spatially and functionally segregated system with medial and lateral cerebellar regions coordinating visual responses to translational and rotational movements, respectively. The lateral region is expressed morphologically as the flocculus—a finger-like extension of the cerebellum projecting between the semicircular canals. The flocculus garners special interest as it is visible on an endocast and exhibits a high degree of size variation among both crown and stem taxa. Such variation raises the possibility that floccular size is correlated with functional and/or behavioral variables that may inform the paleobiology of fossil taxa. Two possibilities have been proposed: (1) floccular variation reflects processing demands of complex flight style, (2) floccular expansion is a response to increasing proprioceptive information generated by the wings. The first hypothesis was rejected in a recent study and we found no evidence to support hypothesis 2. Our data indicate floccular variation is largely explained by body size, and taxa diverging from this general scaling pattern likely do so under the influence of multiple factors. That stated, the semicircular canals and orbit both have strong structural ties with the flocculus that do appear to produce some level of covariation. Establishing morphological relationships between the different components of a sensory network opens considerable space for work in and out of the fossil record.

P2-134 CARUSO, JP; PODOLSKY, RD*; Salem State University, College of Charleston; *podolskyr@cofc.edu*
Effects of personal care product preservatives on the larval development and growth of sea urchins (Arbacia punctulata)
Personal care products (PCPs) comprise a wide variety of daily-use products that contain preservatives to prevent the growth of bacteria and mold. Parabens, the most commonly used preservatives, have been recently implicated in human health issues, causing PCP manufacturers to shift toward alternative preservatives in production and marketing. These compounds enter the ocean but their effects on marine organisms are not well known. This study aimed to test the lethal and sublethal effects of methylparaben (MP), the most widely used paraben, as well as two "safer" alternatives—2-phenoxyethanol (2-PE) and chlorphenesin (CPN)—on early development of the sea urchin *Arbacia punctulata*. Zygotes were added to stirred glass jars with five concentrations of 2-PE, CPN, and MP and allowed to develop in a 48-hour assay. Embryos were staged to record lethal effects, and larvae that had developed to the pluteus stage were measured using skeletal landmarks to estimate sublethal effects on growth. MP, CPN, and 2-PE showed lethal effects at log concentrations of 2, 2.5, and 3 ppm, respectively. Sublethal effects on skeletal growth were evident at log concentrations as low as 1.5 ppm and followed roughly the same order among compounds. Skeletal asymmetry also increased over the same concentrations. These effects on mortality and body size and shape could reduce success in the plankton for sea urchins and other marine invertebrates. Although environmental concentrations are generally lower than those at which harm was detected, more research is needed to understand effects of chronic exposure and the synergistic effects of multiple compounds or environmental stresses like UV and temperature.

88-6 CASAS, J; University of Tours, FRANCE; *casas@univ-tours.fr*
Why do little hairy creatures have so many hairs? Insights from flow sensing in insects
Insects use many hairs of varying lengths for flow sensing. Wood crickets, equipped with an entire hair canopy on their cerci, use them to perceive wolf spiders which are hunting on the ground and launch attacks at high speed once in the neighborhood of their prey. Having measured and modeled the flow ahead of an attacking spider, we then predicted the reaction of the entire canopy of hairs to the transient signals produced. We discovered that hairs of all lengths can be optimal, each one being addressed at a specific instant of the interaction. The extent of negative and positive viscous coupling effects among the sensory hairs, quantified using PIV measurements on bio-inspired physical MEMS models (Micro-Electronical-Mechanical-Systems), seems to reinforce the performance of the entire canopy and might explain its high density. Our work shows that the transient nature of the signal, with its unique signature in time-frequency domain, is key to the understanding of the presence of so many hairs. The long-held assumption that the working of an integrated sensory system could be understood using continuous sine waves on single sensors was proven to be a misleading path, whose origin lies in a strictly physiological approach without consideration for the ecology of the animal. Our approach, very much similar to the one heralded by M. Koehl, rests on the unique power of combining field work to identify the appropriate natural selection factors, elaborate measurements in the laboratory using non-contact laser-based methods and a whole suite of computational, analytical and physical models.

S11-6 CASASA, S*; ZATTARA, EE; MOCZEK, AP; Indiana University, Bloomington, Indiana University, Bloomington; INIBIOMA, CONICET, Argentina; *ascasasa@indiana.edu*
Developmental regulation and evolution of nutrition-responsive growth in horned beetles
Nutrition-responsive development is widespread in nature, and its underlying mechanisms are being elucidated in growing detail. Yet our understanding of how these mechanisms came to be involved in the regulation of nutritional plasticity, and their potential roles in its diversification remains modest. Here we use *Onthophagus* horned beetles to better understand the mechanisms and evolution of nutrition-responsive development of beetle horns, whose development is characterized by varying degrees of nutrition responsiveness. We used comparative RNAseq and RNAi to contrast and functionally investigate the formation of horns in three *Onthophagus* species which exhibit diverse degrees of nutrition-responsive growth, ranging from moderate (ancestral) to extreme (derived) as well as secondarily lost nutrition responsiveness. We find (i) that species with stronger morphological responses to nutrition utilize larger repertoires of differentially expressed genes, and (ii) that genes which ancestrally already possessed nutrition-responsive expression tend to evolve more elaborate nutrition-responsive profiles. Comparative functional analysis of potential regulatory genes is ongoing and includes genes and pathways whose functions in growth regulation are already well established. Among these, we identify the insulin signaling pathway as a major contributor to nutrition-responsive growth and its evolution, both *within* the genus *Onthophagus*, as well as *across* lineages which independently evolved horns and nutrition-responsive horn growth. By combining unbiased, genome-wide assessments with functional evaluations of candidate genes we hope to provide a more comprehensive approach in the regulation and evolution of nutrition-responsive growth development.

P1-49 CASTANEDA, N*; MEHTA, R; University of California, Santa Cruz; *nocastan@ucsc.edu*
Morphology and Kinematics of Suction Feeding In Oxylebius pictus
Predator-prey interactions shape community dynamics through trophic transfer and changes in species composition. Morphology is a crucial factor in feeding interactions, often determining whether a predator can physically consume a prey. In the aquatic environment, fish overcome the density of water via suction feeding, rapidly expanding their buccal cavity to create a pressure differential, resulting in the prey being engulfed in an envelope of water. Suction will often become specialized to certain prey, prey size and prey escape responses, and over ontogeny, predators may change their diet. This study examines the ontogeny of feeding morphology and kinematics of the painted greenling, *Oxylebius pictus*, to understand how morphology and diet are contoured to feeding performance. Using morphometrics and kinematic video analysis, we find feeding performance differences with changes in fish size. On average, larger individuals induced higher prey velocities, yet smaller individuals had quicker, larger excursions. Maximum peak gapes corresponded with maximum velocities for each fish. However, we also find that measures of kinematic performance do not correspond with morphological potential calculated for alcohol specimens revealing behavioral mechanisms or physiological constraints in live fish. This study shows different life stages of the painted greenling are adapted to handle different prey, and certain constraints and behaviors alter feeding performance. Understanding feeding performance of different organisms gives ecologist a better understanding about responses to community changes.

124-4 CASTO, P*; BINGMAN, VP; HEBETS, EA; WIEGMANN, DD; Bowling Green State University, Ohio, University of Nebraska, Lincoln; *pcasto@bgsu.edu*

Evidence for the Distal-Allocentric Representation of Refuge Location in Whip Spiders (Arachnida: Amblypygi)

Whip spiders are a fascinating group of nocturnal predators that navigate back to a refuge after a night of activity in their tropical and subtropical habitat. Their navigational abilities are hypothesized to be under integrated, multisensory control. To further examine the navigational behavior of whip spiders, we performed a series of controlled, repeated laboratory-behavioral experiments using the Costa Rican whip spiders *Paraphrynus laevifrons* and *Phrynus pseudoparvulus*. Point sources of visual, olfactory and tactile cues were placed in a circular arena with an artificial shelter placed in one of five possible locations (one location per subject). After an initial pre-training to establish shelter fidelity, subjects were tested in a series of pre-dawn displacement manipulations and their movements were video tracked. Of particular interest were displacements that occurred when the shelter was removed from the arena, enabling us to examine whether the whip spiders were able to relocate the position of the shelter in the absence of any cues originating from it. Analysis of the subjects' tracks following displacement revealed that they spent more time near the conditioned location of the shelter while it was not present, compared to the other sampled shelter locations in the arena. This supports the hypothesis that whip spiders are able to form a distal-allocentric, spatial representation of a shelter's location reliant on stimuli external to a shelter itself. Additionally, the results of other analyses suggest that under the testing conditions of the arena, and expectantly, light cues play a particularly important role in the efficiency of navigational behavior of whip spiders.

P1-21 CAUDLE, HI*; MEHTA, R; UYENO, TA; CLARK, AJ; College of Charleston, University of California, Santa Cruz, Valdosta State University; *caudlehi@g.cofc.edu*

Are loose skins required for moray eel knotting?

Hagfishes and moray eels might be the only types of fish that use knotting to apprehend prey. Knotting involves concomitant bending and twisting, which apply a combination of tension, shear, and compression to the body's core and skin. In hagfish, the stresses on the skin and core are separated by a subcutaneous venous sinus, which gives the skin its slack appearance and provides space for the core to contort as needed without loading the skin in tension or shear. Hagfish skins placed in tension range from being equally to twice as stiff in the longitudinal axis as in the hoop axis. Conversely, the skins of cartilaginous and bony fishes are taut, preclude exaggerated body core deformations, and are often twice as stiff along the hoop axis. Hagfish also benefit from a derived arrangement of body core muscles that power knotting movements. It is unclear if these adaptations are present in species of morays capable of knotting. We address this question by examining the morphology and material properties of the skins from purple mouth morays (Muraenids that knot), and compared these data with those gathered from American eels (non-knotting Anguillids), Asian swamp eels (non-knotting Synbranchids), and hagfishes (Myxinids that knot). Moray eels are like non-knotting eel species in having taut skins that are firmly connected to serially arranged segments of expaxial and hypaxial muscles. However, like Atlantic hagfish skins, moray skins are isotropic and less stiff than non-knotting eel skins. In contrast to hagfish, knotting in moray eels requires neither loose skin nor complex arrangements of core muscles, therefore, the deformations needed for this behavior are likely achieved by different structural and mechanical features of the Muraenid skin and core.

19-6 CAVES, EM*; ZIPPLE, MN; GREEN, PA; PETERS, S; JOHNSEN, S; NOWICKI, S; Duke University; *eleanor.caves@duke.edu*

Categorical Perception of Color Along a Blue-Green Continuum in Female Zebra Finches

Color stimuli vary continuously, but increasing evidence suggests that color perception can be categorical. Categorical perception is a mechanism by which a perceptual system sorts continuous variation into discrete categories. Two hallmarks of categorical perception are 1) that different stimuli falling on the same side of a perceptual boundary are labeled as belonging to the same category and 2) stimuli falling on different sides of the boundary are discriminated more readily as compared to stimuli that differ by a similar physical magnitude falling within the same category. We have shown previously that female zebra finches (*Taeniopygia guttata*) categorically perceive colors along an orange-red continuum that aligns with the carotenoid-based coloration of male beaks, an important assessment signal in the context of mate choice. Here, we test for categorical perception along a blue-green color range, which has no known signaling function in this species, to ask whether categorical perception is specific to signaling coloration or is a general feature of avian color perception. We trained birds to search for food underneath bicolor discs and then tested for categorical perception by varying the difference between the two colors of the disc. We used a set of equiluminant colors that an established model of avian color discrimination predicts to be approximately equally discriminable from one another. Labeling trials identified the location of potential perceptual boundaries, and discrimination trials then tested for enhanced discrimination between versus within putative categories. Together, these trials show that female zebra finches exhibit categorical perception of a blue-green continuum, but with categories that are less well-defined than those observed in the orange-red range.

84-2 CEASE, AJ*; TRUMPER, EV; OVERSON, RP; Arizona State University, National Agricultural Technology Institute, Argentina; *acease@asu.edu*

Nutritional physiology and ecology of South American locusts Schistocerca cancellata during a 60-year upsurge and roughly 7-fold range expansion

How physiological and ecological factors determine species' population levels across space and time remains a fundamental question in organismal biology. One important area that has received little attention is the role of plant macronutrient availability in determining the success or failure of invasive and sporadically outbreaking species, such as many insect pests, despite the fact that macronutrient balancing has emerged as a key factor regulating animal feeding behavior and performance. Here, we took advantage of the first significant population upsurge of the South American locust, *S. cancellata*, in 60 years. Since 2016 large swarms left their small permanent breeding zone in NW Argentina and invaded Bolivia and Paraguay, as well as an expanded area throughout Argentina. Our field experiments show that wild *S. cancellata* strongly prefer carbohydrate over protein food options, suggesting that these locusts tend to be carbohydrate limited in contrast to the nitrogen limitation hypothesis. Our lab experiments showed that this species self-selected a highly carbohydrate-biased diet when given the option to balance protein and carbohydrate with synthetic diets - a ratio of 1:2 protein:carbohydrate. However, in both Argentina and Bolivia, we found that relatively few plants can provide this protein:carbohydrate ratio. These patterns are consistent with the observed preference for carbohydrate in the field and with our hypothesis that obtaining sufficient carbohydrates is a key, limiting nutrient for these locusts in their permanent breeding zone, and particularly under range expansion.

P1-288 CELLINI, BO*; MONGEAU, J-M; Penn State University; *boc5244@psu.edu*
Decoding the Algorithms for Head and Body Coordination during Visually Guided Flight
In flies, head and wing-driven body movement are coordinated to stabilize gaze, yet the underlying algorithms that permit simultaneous control of the head and body remain elusive. Revealing the algorithms that control the pattern of head and body movement in flight is critical to reverse engineer gaze stabilization because these movement patterns actively shape the visual inputs that enter the brain. Furthermore, it can help us predict the computations that the brain implements to demultiplex sensory inputs for redundant control of multiple-degree-of-freedom flight systems. We use frequency domain analysis to elucidate the tuning and interplay between head and wing movement in rigidly tethered *Drosophila* in virtual reality. Frequency analysis of sinusoidal, visual stimuli showed that head yaw movements were tuned to low frequencies and strongly phase locked at low frequencies. Wing-beat amplitude signals were similarly tuned but were more out of phase than head movements. Coherence analysis and insensitivity to changes in amplitude of sinusoids together suggest that head movements can be modeled with linear dynamics. Wing-beat amplitude signals had an overall lower coherence with the stimuli. These differences could be attributed to the body being fixed while the head is free to move. Analysis of individual trials revealed that head saccade dynamics were broadly tuned. Measurements of the free response of the head demonstrate that the passive neck-head system is highly damped, which may have important implications for passive head stability in flight. Elucidating the algorithms for efficient gaze control during flight can inspire the development of more agile, vision-based aerial vehicles.

56-2 CERVANTES, R*; VANNORDEN, GD; BARNELLO, E; RESTAURO, J; CHAMBERS, E; MAYVILLE, F; SLEE, JB; DeSales University; *rc6881@desales.edu*
Soursop is Truly Sour: Pro-Inflammatory Effects of Annonacin
Annonacin is an acetogenin found in extracts of Annona muricata (Soursoup). Annonacin is thought to exhibit anti-inflammatory properties which could have implications in the treatment of cardiovascular disease and biomaterial rejection. However, annonacin is believed to have pro-inflammatory effects, which could supersede its beneficial effects. Annonacin was extracted from the North American pawpaw fruit using Soxhlet Extraction, and verified using IR, NMR, and UV spectroscopy. The pro-inflammatory effects of annonacin were determined using Bovine Aortic Endothelial Cells (BAOECs) cultured with varying concentrations of annonacin and the adverse effects on cell growth and morphology were studied. An established model of cellular inflammation uses TNFα to induce an accumulation of actin stress fibers. Cells were treated with TNFα, annonacin, or both. These results demonstrate that annonacin alone increases actin stress fiber accumulation beyond TNFα and that there is a synergistic effect of TNFα and annonacin together. Furthermore, BAOECs treated with annonacin for 72 h and imaged every 24 h showed that prolonged exposure to annonacin causes an increase in actin stress fiber production, indicating its pro-inflammatory properties. Taken together, the data suggest that annonacin is pro-inflammatory in vascular endothelial cells which could lead to its cytotoxic effects. To further understand annonacin's pro-inflammatory effects, a THP-1 cell adhesion assay was conducted using polyurethane films. THP-1 cells are a monocyte-derived macrophage cell line which model the body's response to biomaterials. Cell attachment to the polyurethane films was not significantly increased when cultured with annonacin. These studies demonstrate that annonacin is pro-inflammatory in the vasculature but does not significantly increase the immune response to biomaterials.

134-7 CESPEDES, AM*; HOUSLAY, TM ; LAILVAUX, SP; University of New Orleans, University of Cambridge; *anniecespedes@gmail.com*
Individual-level performance trade-offs in male and female Anolis carolinensis lizards
The ecological requirement for performing multiple whole-organism performance tasks places conflicting demands on organismal morphology and physiology. These functional conflicts are the basis for trade-offs in performance expression. Intraspecific performance trade-offs may be masked at the population level, but can become apparent when measured at the level of the individual. We tested for individual level trade-offs among three performance traits (sprinting, endurance, and biting) in green anole lizards. Because relationships among performance abilities in sexually dimorphic species might be sex-specific, we also test whether these trade-offs differ between males and females. We found trade-offs between bite force and sprint speed in females, but among-individual correlations between traits in males showed less obvious patterns. We consider the implications of among- and within-individual variation, as well as the effects of variation among performance trials, for performance trade-offs.

P1-275 CHABAIN, JJ*; SUMMERS, AP; KOLMANN, MA; Friday Harbor Laboratory, University of Washington, Georges Washington University; *jules.chabain@hotmail.fr*
What's The Point? Form and Function of the Caudal Barb in Stingrays
In animals, mechanical defenses can take various shapes, from the protective plates of the armadillo, the venomous spurs of the male platypus, and the quills of the porcupine. Stingrays choose an aggressive way to defend themselves with a whip-like motion of the tail, which drive a serrated spine, called a barb, into predators. Barbs are highly-modified dermal denticles and vary considerably in shape from from the tip to the base, and in terms of serrations shape and number. We used micro-CT scanning to visualize fine-scale barb morphology across 70 species of stingrays, representing around 30% of total taxon diversity, including freshwater potamotrygonids (*Potamotrygon*, *Plesiotrygon*), tropical dasyatid whiprays (*Dasyatis*, *Neotrygon*, *Fluvitrygon*), mollusk-crushing myliobatids (*Myliobatis*, *Rhinoptera*), New and Old World round rays (Urotrygonidae: *Urotrygon*, *Urobatis*; *Urolophidae*), and gymnurid butterfly rays. We then examined the evolution and morphological disparity of barb shape across a time-calibrated molecular phylogeny for all stingrays. We find that barb shape is highly variable, in particular the serrated length of the barb, length of the barb base, and overall number of serrations. Variability is also evident in barb cross-sectional shape, which varies from a flattened blade (*Urotrygon aspidura*) to a more complex, T-shaped bayonet (*Rhinoptera bonasus*). We find no overt morphological distinctions between the barbs of marine vs. freshwater taxa, instead finding more nuanced differences between taxa inhabiting pelagic, reef, deep riverine, and coastal habitats. We discuss using barb morphology as a taxonomic character, especially relevant given their prevalence in chondrichthyan fossil beds, and the ecological significance of the barb as a defensive structure.

P2-68 CHABY, LE*; LIBERZON, I; LISIESKI, MJ; KARAVIDHA, K; PERRINE, SA; Wayne State University, Texas A&M; *lauren.chaby@gmail.com*

Cognitive Flexibility Attenuates the Effects of Severe Stress on Fear Memory and Monoamine Levels in Rat Brains

Individual features, including stress history, can cause variation in cognitive flexibility and in the relationship between cognitive performance and monoamine signaling in the brain. Cognitive flexibility, the ability to incorporate new information in a changing environment, is mediated by reciprocal interactions including monoamine signaling between the striatum and prefrontal cortex. We test the role of cognitive enrichment, in the form of cognitive flexibility training, and variability in cognitive flexibility in attenuating stress induced changes in fear memory and monoamine levels using a rodent model. We found that cognitive flexibility training, alone or followed by severe stress exposure (single prolonged stress), accelerated extinction learning and decreased fear behavior over time during extinction retention, compared with rats without cognitive enrichment. Thus, cognitive flexibility training may attenuate context processing changes resulting from stress exposure. We quantified monoamines in brain regions central to fear learning and cognitive flexibility with high performance liquid chromatography. In the prelimbic cortex, a region vital for maintaining cognitive flexibility and fear suppression, cognitive flexibility training enhanced dopamine (DA) and norepinephrine (NE) in rats with and without severe stress. Conversely, in the striatum, a region mediating reflexive behavior, cognitive flexibility training prior to stress decreased striatal DA. Rats with greater cognitive flexibility performance had a higher striatal DOPAC (a DA metabolite) to DA ratio, thus, cognitive flexibility performance may be facilitated by striatal DA turnover. Our results suggest that cognitive enrichment attenuates effects of stress on behavior and monoamine signaling.

16-4 CHABY, LE*; CAVIGELLI, SA; CHEN, CV; LIBERZON, I; BRAITHWAITE, VA; Wayne State University, Pennsylvania State University, Texas A&M, Texas A&M; *lauren.chaby@gmail.com*

Understanding Apparent Cognitive Enhancements Following Stress in Adolescence: Insights From a Rodent Model

Decades of studies in mammals have shown widespread impairments in behavior and cognition following stress exposure during early development, yet, evidence of seemingly contradictory beneficial effects of stress has been accruing over the course of decades. The number of studies demonstrating apparent enhanced functionality following early stress has shown unprecedented growth, and now spans domains including learning, memory, decision making, and social and reproductive behaviors. The sensitization and specialization hypotheses expand upon prior hypotheses to address how individuals undergo phenotypic changes to specialize and maximize fitness under specific threat conditions, and how phenotypic changes can cause sensitization to specific threat conditions that result in context-specific performance later in life. We have found that rats exposed to stress during adolescence can show lasting enhancements in behavior and cognition including vigilance, problem solving, decision making speed, and reversal learning, and these effects can depend upon threat level. Using a fear learning model, we have recently shown that adolescents differ from adults in their resilience to adverse effects of trauma on context processing and fear learning behaviors. Here, I will discuss our recent findings in the context of the sensitization and specialization hypotheses.

13-3 CHAI, CM*; STERNBERG, PW; California Institute of Technology; *cchai@caltech.edu*

Interneuron Control of C. elegans Diapause Entry

Under adverse environmental conditions, *C. elegans* larvae can choose to enter an alternate stress-resistant diapause state during which metabolic activity and physiological growth are suppressed. *C. elegans* constitutively secretes a mixture of dideoxy sugar ascarylose derivatives that comprise dauer larvae-inducing pheromone and serves as a proxy for high conspecific density. This information about local competition is integrated with other inputs regarding temperature, food availability, and the worm's internal state to assess the environment's suitability for future reproductive growth. Although the roles of *C. elegans*'s amphid sensory neuron classes have been studied using laser cell ablation, little is known about the contributions of other neuron classes. We hypothesized that the AIA interneurons are likely to mediate the pheromone-induced dauer entry decision as they are major postsynaptic partners of the ASK pheromone-sensing neurons. Using genetic silencing and activation techniques, we determined that AIA inhibits dauer entry. We next investigated mechanisms of dauer entry decision execution downstream of AIA. Silencing of the AIB interneurons, which are AIA's major postsynaptic partners, decreased dauer entry suggesting that the AIA-AIB synapse is inhibitory. A loss-of-function mutation of the FMRFamide-like neuropeptide FLP-2 has been shown to exhibit a dauer constitutive phenotype, similar to the AIA-silencing phenotype. Using a transcriptional GFP reporter fusion, we confirmed that *flp-2* is expressed exclusively in AIA. Furthermore, AIA-specific *flp-2* expression in *flp-2* mutant background rescued the mutant phenotype. Our results demonstrate a novel role of the AIA interneurons in mediating *C. elegans* diapause entry and provide insight into the control mechanisms by which AIA orchestrates the decision outcome.

P1-203 CHALLENER, RC; Bellarmine University, Kentucky; *rchallener@bellarmine.edu*

Variability in the State of Regenerating Arms of Asteroids in the Waters of Florida

Arm loss and regeneration in asteroids has been hypothesized to be an important factor that regulates population size. In order to better characterize the state of regenerating arms both between and within species found in the waters surrounding Florida, preserved specimens collected from 1963 - 2015 and stored at the Florida Fish and Wildlife Research Institute were assessed for the presence of regenerating arms. Out of 9316 specimens in the collections, 11.3 % had at least 1 arm regenerating. The incidence of regeneration (% individuals with 1 or more arms regenerating out of total specimens collected) varied between species (1.1 - 40.2 %), but occurred at all depths commonly sampled (< 100 m). Not surprisingly, less robust species such as the luidiids had higher incidences of regeneration and a higher number of arms per individual that were in a state of regeneration. Among species, the average body size (length of longest intact arm) of regenerating individuals ranged from 18.9 to 122.8 mm with *Luidia lawrencei*, the species with the greatest number of specimens (n = 1594) and number of regenerating individuals (n = 424), at an average of 85.4 ± 1.0 mm (mean ± s.e.m.) body size. The greatest number of regenerating individuals (all species) occurred at a salinity of 35.41 ± 0.10 (mean ± sem, n = 275). Several robust species were also found with regenerating arms, including species that have not been previously documented. In addition to regenerating arms, aberrations in the number of arms and in the regeneration process (e.g., split arms) were observed. Although the collection methods (timing, location, depth, method of collection) were not systematic, the results of this study highlight the knowledge that can be gained from access to institute and museum collections.

65-1 CHALLITA, EJ*; SINHA, S; KRUGNER, R; BHAMLA, S; Georgia Institute of Technology, United States Department of Agriculture; *elio.challita@gatech.edu*

Insect pee: How glassy-winged sharpshooters excrete ultrafast fluid droplets

Glassy-winged sharpshooters are agricultural pests that derive nourishment by feeding on xylem fluid in plants. Due to the dilute nutrient content of xylem fluid, sharpshooters ingest 100-300 times their body weight in xylem fluid per day for deriving adequate nourishment. To prevent fluidic build-up within their bodies, sharpshooters continuously excrete fluid in high volumes, creating an effect known as "leafhopper rain". Here, we show that sharpshooters exploit a power-amplifying mechanism to catapult micron-sized droplets excrements away from their body. Using high-speed imaging, we quantitatively describe how sharpshooters use their anal stylus as a biological spring to explosively launch fluid droplets at peak accelerations of 150 m/s^2. Using simple fluid dynamics-based scaling analysis we also show the physical limits on this mode of fluidic pumping. Insight into the underlying principles of this extreme pump holds potential for understanding disease-transmission via plant-sucking insects as well design of bio-inspired pumps for microfluidic applications.

90-5 CHAMPAGNE, CD*; KHUDYAKOV, JI; MCCORMLEY, MC; DEYARMIN, JS; HOUSER, DS; CROCKER, DE; National Marine Mammal Foundation, Univ. of the Pacific, Sonoma State University; *cory.champagne@nmmf.org*

Metabolic response to acute and repeated stress in the northern elephant seal

Glucocorticoid release following acute stress causes metabolic alterations that facilitate the response to, and recovery from, immediate stress. Repeated or chronic stress, however, can result in persistent activation of the stress response with maladaptive consequences. We investigated the metabolic consequences to repeated stress in a well-studied marine mammal, the northern elephant seal, by repeated administration of ACTH over four consecutive days. Blood samples were collected for eight hours following ACTH administration on days 1 and 4 to characterize the acute and chronic responses, respectively. The metabolic response to stress was assessed using non-targeted metabolomics. 388 biochemicals were detected; of these, 281 compounds of multiple classes (e.g. lipids, amino acids) showed a significant change during the study ($p+q<0.05$), suggesting a wide-ranging metabolic response. Stress induction was associated with lipid mobilization, evidenced by increased concentrations of circulating free fatty acids. The magnitude of the circulating lipid response was greater in the acute than in the chronic stress state ($p<0.05$). Several amino acids (e.g. alanine, lysine, tyrosine) declined during the stress response ($p<0.05$); without a related increase in TCA cycle or urea cycle intermediates, suggesting either reduced protein catabolism or increased amino acid uptake and resynthesis. Thus, glucocorticoid release may be associated with protein conservation in this fasting adapted species. No single biochemical was unique to acute or chronic stress, but patterns of biochemicals might be useful indicators that distinguish between acute and chronic stress states in this and potentially other species.

P3-81 CHAN, S.F.*; WANG, W; Guangdong Ocean University; *siuming573@sina.com*

Molecular characterization of the myostatin cDNA (MrMstn) from the fresh water shrimp Macrobrachium rosenbergii

The long and short forms full-length myostatin cDNA (MrMstn) for the fresh water shrimp Macrobrachium rosenbergii had been cloned and characterized. Amino acid sequence analysis revealed that the two cDNAs are identical in the overlapping propeptide region. Sequence alignment and phylogenetic analysis revealed that all myostatins are evolutionary related and their amino acid sequences are highly conserved at the C-terminal end. Results from expression studies indicated that MrMstn is widely expressed in different tissues including the eyestalk, hepatopancreas, muscle, and heart, etc. Furthermore, the expression level of MrMstn in the muscle is the highest in late post-molt stage (stage B). MrMstn could be detected in different life cycle stages including the ovary, early embryo, post-larvae, juveniles, subadult and adults. Additionally, the expression level decreased from early to advanced life stages. RT-PCR cloning of MrMstn from shrimp of different life cycle stages revealed that MrMstn cDNA is highly polymorphic. Different alternatively splicing variants could be identified in different tissues and different life cycle stages. Transcript variants that consist of truncated N-terminal or C-terminal end could be identified as well as deletion of different cDNAs. The synthesis of different alternatively spliced transcripts would increase the proteome diversity and might have a regulatory role in controlling the equilibrium of functional MrMstn in vivo. Although no muscle doubling was observed in the injected shrimp, as reflected from the low transcription rate of the myosin and b-actin, the expression of other genes such as myocyte enhancing factor and follistatin were affected. This study could further enhance our understanding of the role of myostatin in shrimp.

7-6 CHANG, E*; LENTINK, D; Stanford University; *echang7@stanford.edu*

A Bio-hybrid Morphing Tail for Vertical Tailless Gliding Flight

Little is known about how birds utilize tail morphing while maintaining yaw stability in gliding, maneuvering flight. To address this gap in our understanding of avian flight, we developed a flying bio-hybrid morphing tail robot that utilizes 12 tail feathers from pigeons (*Columba livia*). The articulated tail mechanism is capable of four degrees of freedom inspired from avian tail motion during flight: spread/furl, elevation/depression, twist, and yaw. The feather motion needed for spreading and furling is accomplished with underactuation, a concept that has been shown to successfully enable feather motion in morphing bird wings. The distal tail feathers are actively actuated and elastic bands that link each feather underactuate the remaining feathers. We tested the tail mechanism on a fixed-wing robot that logs position and orientation data of the body and tail during untethered flight. This work allows us to test theories on bird flight control strategies which will provide inspiration for future supermaneuverable flying robots.

80-4 CHANG, B*; MYOUNG, J; VIROT, E; CLANET, C; KIM, H.-Y.; JUNG, S; Virginia Tech, Seoul National University, Harvard University, LadHyX, Virginia Tech, Cornell University; *bchang5@vt.edu*

How Aquatic Animals Jump Out of Water

Many aquatic animals jump out of water to hunt or escape predators. In this study, we investigate the physical conditions required for animals to leap out of water. The animals analyzed ranged from 10^{-3} to 10^{1} meters in size. We find that the normalized jumping height, H/L, scales with animal length as $H/L \sim L^{-1/3}$. We elucidate this behavior by balancing power produced by the animal with drag-induced dissipation. Simplified experiments were conducted with axisymmetric bodies and a bio-inspired robot, which show some effect due to entrained fluid mass. We find that larger ratios of body mass to entrained fluid mass will allow jumping heights in a similar range as animals.

P3-71 CHANG, E.S.*; CARTWRIGHT, P.; University of Kansas , University of Kansas; *eschang1@gmail.com*

Identification of conserved genetic elements within the cnidarian class Hydrozoa and their utility for detection of cryptic genetic diversity in the holopelagic jellyfish Liriope tetraphylla

Given the amount of publicly available genomic sequence data, new avenues to incorporate pre-existing data with newly-sequenced data are especially relevant. One challenge in combining data sets for use in evolutionary applications is the assessment of which loci between different genomes are homologous with one another, and then assembling the relevant segments of the genome for those taxa only available as raw sequence data. We took a combined ultra-conserved-element bait-design approach and an automated target-restricted assembly approach to make use of low-coverage whole-genome data sets for population genomic analyses of the holopelagic hydrozoan *Liriope tetraphylla*. We combined previously-developed software pipelines to identify homologous loci in several pre-existing, fully-assembled hydrozoan genomes. We then identified these loci in our set of raw reads from globally sampled individuals of *L. tetraphylla*. We report the successful identification and assembly of conserved elements from several taxa across the subphylum and we tested the utility of these loci to address questions at multiple evolutionary scales in *L. tetraphylla*. Our results point to a novel use of raw sequencing libraries or assembled genomes from publicly available data sets. We anticipate future investigation into the nature of these conserved loci may allow their application to deeper phylogenetic questions within Hydrozoa.

61-4 CHANG, J*; ALFARO, ME; RABOSKY, DL; Univ. of Michigan, Ann Arbor, Univ. of California, Los Angeles; *jonathan.chang@ucla.edu*

Extending and remixing the complete ray-finned fish tree of life via fishtreeoflife.org

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. Using phylogenetic trees has been critical for comparative researchers investigating problems in ecology, evolution, and biodiversity. Although progress has been made in accessing phylogenetic resources, there is still a need for a resource that is comprehensive, scriptable, and easily accessible by researchers of all levels of expertise. We introduce the Fish Tree of Life website and R package fishtree, resources to provide convenient access to sequences, phylogenies, fossil calibrations, and diversification rates for ray-finned fishes. We demonstrate the functionality through its application to phylogenetic inference and comparative studies, and show its ability to integrate with other popular R packages. These tools make access to phylogenies and diversification data accessible to empiricists. We close by showing how we are making progress on both automatic and machine-assisted curated updates to the fish tree of life.

P2-73 CHAPPELL, DC*; SPEISER, DI; Univ. of South Carolina, Columbia; *danielrc@email.sc.edu*

Neuroethology of the distributed visual system of the eyed chiton Acanthopleura granulata.

Most research on visual systems has focused on animals with paired cephalic eyes; however, some animals have many eyes distributed across their body. Some of 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 relationships between eye structure and light-influenced behaviors, 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 their critical flicker fusion rate which was found to be 35-40 Hz. Next, to test 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 may present a computational hurdle to its simple nervous system, it seems to mitigate this by processing visual information with a neural circuit design used by other animals to process distributed mechanosensory information.

P3-100 CHARMANTIER, G*; LORIN-NEBEL, C; MATHERS, N; GERBER, L; LEE, CE; Univ. of Montpellier, France, Univ. of Wisconsin, Madison, Univ. of Wisconsin, Madison; *guy.charmantier@umontpellier.fr*

Key ion transporters Na^+/H^+ antiporter (NHA), V-H^+-ATPase (VHA) and Na^+/K^+-ATPase (NKA) are implicated during evolutionary transitions from saline to freshwater habitats in the copepod Eurytemora affinis

Colonizations from marine to freshwater (FW) environments constitute major evolutionary transitions and pose osmoregulatory challenges for organisms. The copepod *Eurytemora affinis* has recently invaded FW habitats multiple times independently in the Northern Hemisphere. We found evolutionary shifts in osmoregulatory capacity in *E. affinis*, with increased hemolymph osmolality at lower salinities in FW populations relative to their saline ancestors. Novel osmoregulatory structures, the "Crusalis organs," were located at the 5 pairs of swimming legs. In their ionocytes, immunolocalization and *in situ* expression revealed the presence of basolateral NKA, apical VHA and apical NHA. VHA expression and activity were higher in FW populations relative to their saline ancestors, which arose from increased abundance of VHA per cell, rather than increased number of ionocytes. For the first time in a crustacean we revealed the presence of NHA, with eight paralogs of NHA in the comprehensive genome of *E. affinis*. Using specific antibodies, we localized the NHA-7 paralog in ionocytes of the swimming legs where it colocalized apically with VHA. Hence, we propose that NHA is involved in the uptake of Na^+ in FW using the electric gradient generated by VHA, in association with the transfer of Na^+ to the hemolymph by NKA. Such results provide insights into mechanisms of ionic regulation, with added insights into evolutionary mechanisms underlying physiological adaptation during habitat invasions.

28-2 CHEAM, D.*; HUEFFMEIER, B.W.; NISHIGUCHI, M.K.; New Mexico State University; *dcheam@nmsu.edu*

Noshing on Vibrio - How Grazing "Outside the Host" Determines "Fitness Inside the Host"

Vibrio fischeri can aggregate under stable conditions as a nonmobile community called a biofilm. Certain protozoans have a preference to feed on biofilms depending on the age and type of bacteria within the biofilm community. Protist grazing pressure can have multiple effects on bacterial biofilms including decreasing growth rates to triggering defense mechanisms that confer an increase in fitness. *V. fischeri* is a bacterial symbiont that resides in the light organs of sepiolid squids, forming a beneficial association by producing luminescence for a behavior termed counter-illumination. During the symbiosis, *Vibrio* bacteria produce biofilms within the squid light organ, allowing them to grow in high cell density, which regulates luminescence production. Given that *Vibrio* bacteria form biofilms both outside and inside the squid host, various factors may select for specific attributes for optimal biofilm production. Therefore, we examined whether biotic factors (e.g. grazing) outside the squid host were important for increasing biofilm production during symbiosis. We measured a total of nine different strains (free-living and symbiotic) of *V. fischeri* to determine whether free-living or symbiotic strains differed in their ability to form biofilm by experimentally evolving these strains for 500 generations under protozoan grazing pressure. Early (4 hour) or late (24 hour) biofilms at every 100 generations were subsequently examined for their ability to colonize juvenile squid hosts. *V. fischeri* are capable of evolving various defense mechanisms due to protist grazing pressure, which eventually effects the fitness during symbiosis with their squid hosts. Results of this study will provide a window to specific trade-offs that occur between abiotic and biotic pressures during environmentally transmitted beneficial associations.

5-1 CHELINI, MC*; EDWARDS, DL; Univ. of California, Merced; *mcchelini@gmail.com*

Malaria as a Mediator of Sexual Dimorphism in Western Fence Lizards (Sceloporus occidentalis)

Sexual dimorphism is typically treated as a consequence of sex-specific reproductive benefits. Environmental factors may, however, determine or modulate the costs and benefits associated to certain phenotypes. In species distributed along steep environmental gradients, populations may differ in their degree of sexual dimorphism as a consequence of local adaptation. Western fence lizards (*Sceloporus occidentalis*) present great variation in size, color pattern and degree of sexual dimorphism across their distribution. This species is often infected with lizard malaria, transmitted by *Plasmodium mexicanum*. Malaria reduces infected males speed, aggressiveness, and territoriality, and infects disproportionately more larger and brightly colored males. Malaria may, therefore, bring a cost to large and brightly colored males, while reducing the sexual benefits associated with those traits. We aim to determine the influence of malaria on the evolution of intraspecific phenotypic variation by understanding how the spatial structure of the malaria parasite *P. mexicanum* relates to phenotypic variation in Western fence lizards. More specifically, we test the prediction that a population's degree of sexual dimorphism is inversely related to the prevalence of malaria in its environment. By collecting morphological and ecological data on specimens from across California, we show that female and male phenotypes respond to environmental variables differently, resulting in intraspecific differences in degree of sexual dimorphism. We also show that the prevalence of malaria is extremely patchy, and relate it to differences in lizard morphology. Our results show that parasites may be an important mediator of sexual selection and that natural selection, through local adaptation, is a potential driver of sexual dimorphism.

34-6 CHENEY, JA; STEVENSON, JPJ*; DURSTON, NE; USHERWOOD, JR; BOMPHREY, RJ; WINDSOR, SP; Royal Vet. College, Hatfield, UK, Univ. of Bristol, UK; *jonathan.stevenson@bristol.ac.uk*

Avian gust rejection in gliding flight through updrafts

Gusts and turbulence present serious challenges to flying birds. In windy conditions, gust magnitudes can be similar to avian flight speeds, with the potential to cause rapid attitude and flight path deviations. Birds appear to counter this by changes to the pose and shape of their wings and tail, which indicates either a strong gust mitigation strategy and/or rapid recovery movements. To understand the impact of gusts on birds in steady gliding flight, we flew two individuals, a barn owl (*Tyto alba*) and a goshawk (*Accipiter gentilis*), along a straight indoor corridor through an acute updraft. Each flight was recorded using an array of high-speed cameras positioned above and below the flight path. We used photogrammetric image-matching techniques to reconstruct 3D point-clouds of each bird's dynamic surface geometry throughout the updraft event. Both birds altered their wing morphology and maintained a level flight trajectory with minor changes in attitude; by comparison, a stiff-winged model glider of similar scale experienced large vertical and pitch deviations. We investigate the initial rejection of the perturbation by the birds' wings for multiple gust strengths, including the relative contributions of rigid-body motion and morphing shape-change. For both individuals, wing deflection appeared to result in body stabilization through aeroelastic mechanisms.

P3-59 CHEU, AY*; BERGMANN, PJ; Clark University;
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Ontogenetic allometry of locomotor performance in basilisks

Muscles generate the force needed for locomotion, which is crucial for an animal's ability to perform fitness-relevant tasks in a heterogeneous environment. In whole-organism performance, such as terrestrial walking or sprinting, different tasks require multiple muscles to be activated in patterns constituted by varying intensities and times. Direct relationships, redundancy and multitasking are inherent parts of muscle function. Direct relationships and redundancy occur when different muscles have specific roles, yet often work together to accomplish tasks and allow for movement. Multitasking happens when a single muscle contributes to multiple tasks. This multi-functionality of muscles and variation in activation pattern allow for the successful completion of a wide range of locomotor tasks with a single set of muscles in different ecological contexts. Terrestrial and aquatic locomotion can place different muscular demands on an animal. Aquatic locomotion often involves predominantly sinusoidal oscillations of the body to propel the animal horizontally through the water while terrestrial involves limb movements to carry the body over the substrate with lateral undulation playing a smaller role. Because the morphological properties of muscle do not change as an animal switches locomotor tasks, an important question is how does the function of a set of locomotor muscles differ between locomotor modes such as running, jumping, climbing, and swimming? We address this by looking at differences in in vivo motor patterns of the mm. caudofemoralis longus, pubioischiotibialis, gastrocnemius major, and tibialis longus in the hindlimbs of *Basiliscus vittatus* lizards while performing these modes of locomotion. We show that activation patterns vary during running, jumping, climbing, and swimming.

15-4 CHILDRESS, M/J*; SMITH, K/M; NOONAN, K/R; BERTELSEN, R/D; Clemson University, Florida Marine Research Institute - FWC; *mchildr@clemson.edu*

Using Acoustic Telemetry to Study Behavior and Habitat Associations in Stoplight Parrotfish and Caribbean Spiny Lobsters

Understanding the factors that influence habitat use of coral reef organisms is increasingly important as reefs shift away from a structurally complex hard coral dominated community to a flattened soft coral / sponge dominated community. However, our ability to study fine scale habitat use of marked individuals has been limited to inferences drawn from periodic diver census data. Here we describe the benefits and limitations of using acoustic telemetry data to ascertain measures of den location, habitat use, daily home range, and social interactions for stoplight parrotfish and Caribbean spiny lobsters. Our study focused on a set of nearshore coral patch reefs in the middle Florida Keys with an array of 32 Vemco VR2 receivers placed in a hexagonal grid pattern. Individual lobsters and parrotfish were captured, tagged, and released over four summers from 2015-2018. Diver surveys provided quantitative estimates of reef substrate composition, reef fish abundance, and structural complexity for a majority of patch reefs within the array. Caribbean spiny lobsters show a clear pattern of homing to a common crevice shelter while often foraging at night in different patches of habitat. Terminal phase stoplight parrotfish tend to have a home range limited to one or two adjacent reefs which can overlap with other supermales. While the physical structure of patch reefs is clearly important to home range sizes and den locations of both lobsters and parrotfish, the abundance and species composition of live hard coral is not a strong predictor of their current habitat use. Thus, the flattening of coral reefs is likely to have significant impacts on the behavior and habitat use of reef organisms.

138-7 CHIN, DD*; LENTINK, D; Stanford University;
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Avian locomotion strategies during arboreal foraging

Arboreal birds frequently hop and fly among tree branches to search for food. In the process, they must maneuver around intervening leaves or branches that obstruct flight paths between reliable perches. To understand the tradeoffs in time, effort, and safety made during these flights, we studied voluntary, perch-to-perch flights made by Pacific parrotlets (*Forpus coelestis*) in a novel aerodynamic force platform. This setup enables direct, *in vivo* measurements of the vertical and horizontal aerodynamic forces produced by the birds during flight. To study how birds adapt their flight path when an obstacle is present, we compare the aerodynamics and high-speed kinematics of flights made with and without a horizontal string obstructing the path between two instrumented perches. These measurements are used to develop a new model for assessing the implications of their flight strategies on time and energetic cost. The model can be further generalized to analyze locomotion strategies employed by other animals or improve bimodal robots traversing cluttered environments.

P3-94 CHIPARUS, SL*; ZAHOR, DL; GLYNN, KJ; CORNELIUS , JM; Eastern Michigan University ; *schiparu@emich.edu*

The influence of metal exposure on plumage coloration in several songbird species

Heavy metals are found naturally in the environment but can be elevated beyond normal levels due to anthropogenic activities. Heavy metals continue to pollute many ecosystems in spite of emission control measures, potentially due to historical exposure or the continued expansion of human development. Organisms exposed to metal pollutants may be negatively impacted if fitness is reduced. The spread of metal pollutants into important ecological systems demands biological indicators that give insight into the local environmental health. Carotenoid-based bright plumage in many songbird species is thought to be a visual cue to potential mates - signaling high fitness levels. This is because bright plumage may reflect efficient foraging for diet-dependent carotenoids and/or the ability to allocate carotenoids to plumage coloration as opposed to anti-oxidant protection. Studies have shown a decline in carotenoid-based coloration along metal pollution gradients, and an increase in melanin patch size with increased metal exposure. We will relate plumage coloration characteristics of urban and rural American Goldfinches (*Spinus tristis*) and American Robins (*Turdus migratorius*) to feather mercury levels. Identifying negative impacts of pollutants on wild animals are important for understanding the consequences of anthropogenic activities on wildlife.

23-1 CHIPMAN, AD; The Hebrew University of Jerusalem; *ariel.chipman@huji.ac.il*

Oncopeltus, Tribolium, Drosophila - a three-taxon problem for understanding the evolution of segmentation in insects

Reconstructing a sequence of evolutionary events requires as a minimum a comparison among three taxa - two sister taxa and an outgroup. For understanding the evolution of segmentation in insects, we have three ideally positioned species, which form such a three-taxon group: The fruitfly *Drosophila melanogaster* and the red flour beetle *Tribolium castaneum* form a sister group relationship within Holometabola, while the milkweed bug *Oncopeltus fasciatus* forms a hemimetabolous outgroup. We have been focusing on *Oncopeltus*, dissecting its segmentation process in detail. Our results offer a comparative view and allow a reconstruction of the stages in the evolution of the different segmentation modes in insects. We have previously shown that simultaneous segmentation most likely appeared before the origin of Holometabola, and has been lost several times, including in *Tribolium*. We now add details about the evolution of different modes of sequential segmentation. We present the cascade involved in differentiating new segments from a posterior growth zone, and show that a hierarchy reminiscent of the classical *Drosophila* hierarchy is found in sequential segmentation as well. The cascade begins with primary pair-rule genes followed by secondary pair-rule genes, which regulate segment polarity genes. The cascade is highly redundant and RNAi phenotypes of most genes are surprisingly minor. This hierarchy was most likely ancestrally of a single-segment periodicity. However, there is evidence for a two-segment periodicity in the differentiation of the segments after their formation in *Oncopeltus*, perhaps giving a hint to the origin of the pair-rule pattern found in both *Tribolium* and *Drosophila*.

111-3 CHISM, G*; FARON, W; DAVIDOWITZ, G; DORNHAUS, A; Univ. of Arizona, Tucson; *gchism@email.arizona.edu*

The influence of nest architecture on colony organization in the ant Temnothorax rugatulus

No organism, during at least some portion of its life, is free from spatial constraints within their dynamic environments. For some organisms, a near sessile life history mandates a strategic placement of where they live. Potential constraints can be solved with an organism's ‘extended phenotype', or traits that extend into the environment: for example, in social insects, the nest, built by the colony, then can serve as a mechanism for microclimate regulation. Ants can thus change their local environments to the benefit of colony survival. Much attention has been given how organisms shape their extended phenotypes (e.g. nest architecture), while largely ignoring how organisms interpret them. The ant *Temnothorax rugatulus* provides an ideal model system to investigate the effects of nest architecture on colony organization, thus providing insight into the interactions between nest environment and its occupant. We tested the hypotheses that (i) nest architecture affects worker and brood spatial distribution, in particular (ii) that nest architecture would determine extent and distribution of spatial fidelity zones (‘micro-territories') of workers in the nest, and that (iii) nest architectures promote different worker movement patterns. We use space syntax theory (structural accessibility) to determine the influence of the structural network of the nest on the colony organization. Besides investigating the feedback between nest architecture and colony organization, our results may provide implications of nest accessibility on microclimate regulation.

52-5 CHMURA, HE*; ZHANG, V; WILBUR, SM; BARNES, BM ; BUCK, CL; WILLIAMS, CT; Univ. of Alaska Fairbanks, Northern Arizona Univ.; *hchmura@alaska.edu*

Does the Early Squirrel Get the Girl?: Chronotype in the Arctic Ground Squirrel

Chronotypes, or repeatable between-individual differences in circadian behavior and/ or physiology, have been demonstrated in numerous taxa, including humans. When important behaviors such foraging and mating or periods of rest and activity are timed differently across individuals, they have the potential to generate fitness differences, and may be under both natural and sexual selection. Despite the potential biological importance of individual chronotypes, few chronotype studies have been conducted in free-living animals. In this study, we asked what factors regulate activity patterns in free-living arctic ground squirrels and hypothesized that daily burrow immergence and emergence times are influenced by individual chronotype as well as local environmental conditions. We tested this expectation by monitoring daily immergence and emergence times of free-living arctic ground squirrels using collar mounted light loggers across the 2014-2016 spring and summer seasons. We discuss the extent to which daily patterns of activity exhibit repeatable between-individual differences and how they vary between the sexes and across the active season. We evaluate our findings in light of the changing selective pressures facing arctic ground squirrels as they transition between periods of mate competition, parental care, and preparation for hibernation.

P2-1 CHOMENTOWSKA, A*; MILLER, JS; Yale University, Amherst College; *anri.chomentowska@yale.edu*

Variation in interspecific reproductive barriers between Solanum species

Interspecific reproductive barriers (IRBs) prevent hybridization and establish species integrity. Recent research has suggested that molecular mechanisms of interspecific incompatibility in plants are intimately related to that of gametophytic self-incompatibility, a mating system that establishes obligatory outcrossing between individuals of the same species via pollen-pistil interactions. We investigated the presence and direction IRBs among closely related species in the wild tomato clade (*Solanum* section *Lycopersicon*). We conducted reciprocal crosses between self-incompatible (SI) *S. arcanum* and self-compatible (SC) population of mostly SI *S. peruvianum* which lacks the expression of the female determinant gene of SI (*S-RNase*), and measured fruit and seed set. Additionally, we conducted crosses between SI *S. arcanum* and SC *S. pimpinellifolium* which is polymorphic in functionality of pollen-side SI factor (Cullin1). We found that SI *S. arcanum* and SC population of *S. peruvianum* were compatible only in one direction. Crosses between SC *S. peruvianum* (dam) and SI *S. arcanum* (sire) resulted in an average of 46.9% fruit set, while the reciprocal cross failed to set any fruit. However, there were associated fitness costs of hybridization in the fruits produced. Unlike the results for crosses between SI *S. arcanum* and SC *S. peruvianum*, crosses between SI *S. arcanum* and SC *S. pimpinellifolium* were compatible in both directions regardless of Cullin1 functionality. The variation of IRBs shown here complicates assumptions about how mating systems can predict the outcomes of interspecific incompatibilities and suggests that the establishment of IRBs involves uncharacterized complexities. This study contributes to the integration of molecular mechanisms and evolutionary consequences of interspecific interaction.

47-3 CHOU, A*; SAYRE, ME; CRONIN, TW; Univ. of Maryland Baltimore County, Univ. of Arizona; *achou2@umbc.edu*

Structure through the stages: development of the central complex in predatory arthropods

Animal behavior and ecology change with development, often with altered brain morphology and function. In arthropods, the central complex (CX) is a highly conserved region involved in sensory integration, action selection, and orientation. In insects, it consists of a protocerebral bridge (PB), a central body (CB) including the fan-shaped body (FB) and ellipsoid body (EB), and paired noduli (NO). The timing of CX formation varies among insect taxa, ranging from embryogenesis to gradual completion postembryonically, perhaps related to the development of sensory and motor abilities. Malacostracan crustacean CXs are generally simpler, with a v-shaped PB and a spindle-shaped CB. However, in members of the order Stomatopoda (mantis shrimps), the CX resembles that of insects. These marine arthropods possess complex vision and destructive predatory behaviors. They have well-developed, modular PBs and CBs and are the only crustaceans known with NO-like paired neuropils and an EB-like neuropil below the CB. Unlike adults, larvae are planktonic and could have reduced sensory and behavioral complexity. However, observations reveal a wider range of motor control, including prey capture behavior, than most larval crustaceans. Here, we compare the development of the CX in *Neogonodactlyus oerstedii* larvae to that in predatory insect larvae. Immunolabeling of early stage *N. oerstedii* larvae with antisera raised against RII (a regulatory subunit of PKA), serotonin, FMRFamide, and GAD (a precursor to GABA) reveals all subunits present in adult CX, including NO-like and EB-like neuropils. However, the v-shaped PB resembles that of other malacostracans. This is the first description of CX development in a crustacean - one with spectacular vision and behavior - and provides a basis for comparing CX neural development in two distantly related taxa with similar feeding ecologies.

77-1 CHOUDHURY, M; MCCLEARY, RJR*; KESHERWANI, M; KINI, RM; VELMURUGAN, D; University of Madras, Stetson University, National University of Singapore; *19venom84@gmail.com*

A Multi-Technique Comparison of the Venoms of Two Medically-Important Elapid Snakes, the Indian Cobra (Naja naja) and the Common Krait (Bungarus caeruleus)

In some areas of the world, bites from venomous snakes cause significant human mortality and morbidity. In India, it is estimated that ~81,000 people are bitten by venomous snakes per year, which includes ~11,000 mortalities. A large percentage of these bites are attributed to four species of snakes, but studies of the venoms of those species are sparse. We used three different proteomics techniques to characterize the venom proteomes of two of the major species involved, the Indian cobra (*Naja naja*) and the common krait (*Bungarus caeruleus*), both of which belong to the family Elapidae. Techniques included: 1) in-solution tryptic digestion of crude venoms followed by electrospray tandem mass spectrometry (ESI-LC-MS/MS), 2) in-gel tryptic digestion of venom components that were separated by protein gel electrophoresis (SDS-PAGE) followed by ESI-LC-MS/MS, and 3) in-solution tryptic digestion of venom components separated via gel filtration chromatography followed by ESI-LC-MS/MS. The use of multiple techniques allowed for identification of a greater number of protein toxins than were recovered by any single technique alone, although the relative increase by any one technique was different between the two snake species. Overall, 81 and 46 different proteins were detected in the venoms of *N. naja* and *B. caeruleus*, respectively, and *Naja naja* venom was more complex than *B. caeruleus* venom. Although the three-finger toxin and phospholipase A_2 families were highly represented in both venoms, the specific percentages were different between the two, as were the presence or absence of other toxin families. These results give a greater understanding of the complexity and composition of the venoms of these two important snake species.

P2-121 CHRISLER, AD*; GRANT, A; KIMBALL, MG; CAPASSO, DM; JOHNSON, EE; MALISCH, JL; St. Mary's College of Maryland, University of Nevada, Reno; *adchrisler@smcm.edu*

Predictors of glucocorticoid and glucose mobilization in response to an acute handling challenge in Mountain White-crowned Sparrows (Zonotrichia leucophrys oriantha)

Acute challenges initiate a suite of physiological responses including activation of the sympathetic nervous system and hypothalamic-pituitary-adrenal axis. Collectively these responses promote energy mobilization and resource allocation to support survival. Here we characterized the glucocorticoid and hyperglycemic response to a standard acute handling stressor in a free-living population of Mountain White-crowned Sparrows and modeled potential predictors of the glucose and glucocorticoid response to challenge. Sparrows were trapped in seed-baited potter traps at Tioga Pass Meadow, CA during the early-mid breeding season (May-June, 2018). Blood samples were collected at 0, 15 and 30 min post-capture. Blood glucose was quantified in the field using a FreeStyle Lite meter, and glucocorticoid levels were analyzed in the lab. Consistent with previous research in this population, blood glucose and glucocorticoid levels respond positively to challenge. Glucose increased 34% above baseline by 15 min and 54% 30 minutes post capture. Glucocorticoid levels increased 309% above baseline by 15 min and 500% by 30 min post-capture. Potential predictors of glucose and glucocorticoid mobilization were modeled using scaled body mass, fat score, hematocrit, sex, date and bleed delay time as variables. The most prominent predictor of both glucocorticoid and glucose mobilization was fat score. These results suggest that stored lipid-based resources influence the physiological response to stress. Future studies should examine additional energy substrates such as triglycerides and cholesterol to further tease apart the physiological response to challenge.

P2-102 CHRISTIANO, B.M.*; HOWEY, C.A.F; University of Scranton; *brandi.christiano@scranton.edu*

Do timber rattlesnakes with larger home ranges maintain higher baseline corticosterone levels?

Glucocorticoids are hormones that free up energy so that an organism can deal with a "stressor". As addressed by the Reactive Scope Model (Romero et al. 2009), "stressors" can include predictive daily, seasonal, or lifetime changes with regard to the life history of the organism. For example, organisms may maintain elevated glucocorticoid levels during times of the year when they are more active, searching out mates or foraging. The objective of our study was to determine if individual timber rattlesnakes (*Crotalus horridus*) that maintain larger home ranges and increased movement rates at the same time of the year also maintain higher baseline glucocorticoid levels. We radio-tracked timber rattlesnakes (n = 20) for two years (2016 and 2017) and collected blood samples from individuals in August of each year. We determined corticosteroid levels for each blood sample using a competitive enzymeimmunoassay in the lab. We determined movement rates and home range sizes using radio locations for each individual within ArcGIS. We compared individual movement rates and home range sizes with baseline corticosterone levels using a mixed-model linear regression. Results from this study can assist biologists in interpreting the effect of behaviors on an animal's physiology and further assist in the definition of a "stressor".

93-1 CHUN, C*; BISWAS, T; BHANDAWAT, V; Duke Univ., Loyola Univ. of New Orleans; *cc583@duke.edu*

General Template Model for Insect Locomotion

Despite vast differences in animals' size and number of legs, the trajectory of the center of mass (CoM) during locomotion can be described with simple mechanical models. For example, when running, cockroach and human decelerate to the lowest speed at midstance, which can be modeled as a spring-loaded inverted pendulum (SLIP). Here, we investigated the locomotion of *Drosophila* because a recent study showed that its slow speed imposed a challenge to SLIP, and because we wanted to leverage its versatile genetic toolbox to obtain a deeper insight into control of insect locomotion. Through automated data acquisition and processing, we analyzed >1000 steps at a range of speeds; at all speeds, flies predominantly used a tripod gait. We found that the fly's CoM was at its highest height and speed at midstance. Since this kinematics was inconsistent with SLIP, we used a new model - angular and radial spring-loaded inverted pendulum (ARSLIP) - which is a modified SLIP with an angular spring ankle. The combination of angular and radial spring could either decelerate or accelerate CoM before midstance, and therefore could model a range of CoM kinematics including those of both cockroach and fly. For each step, we also estimated spring constants of ARSLIP from a spread of tripod legs by assuming a tripod as a point mass supported by three springy legs. The estimated values matched values optimized to fly kinematics. We also examined the role of sensory feedback by silencing sensory neurons in the legs. Interestingly, the sensory deprived flies maintained tripod gait and had similar kinematics to the wild type flies. In sum, the diverse kinematics observed in insects represent different regimes of the ARSLIP model, and the basic characteristics of insect locomotion is created through feedforward signals and mechanics of a tripod.

2-1 CHUNG, AK*; COX, RM; COX, CL; Georgia Southern University, Univ. of Virginia; *ac10578@georgiasouthern.edu*

Ontogenetic increases in sex-biased gene expression vary across tissues in a sexually dimorphic lizard

Sexually dimorphic species produce distinct male and female phenotypes from a single, shared genome, which can be achieved through sex-specific regulation of gene expression. Although sex-biased gene expression is generally predicted to increase over ontogeny as male and female phenotypes diverge, this pattern should be most pronounced in tissues that contribute to the most extreme aspects of sexual dimorphism. However, most previous characterizations of sex-biased gene expression have looked at either 1) multiple tissues at a single time point or 2) single tissues at multiple time points, thus ignoring how sex-specific development is coordinated across multiple tissues over time. In the brown anole, a lizard that exhibits extreme sexual size dimorphism, we used RNA-Seq to analyze liver, muscle, and brain transcriptomes at 1, 4, 8, and 12 months of age to simultaneously characterize sex-, age-, and tissue-specificity of gene expression. We predicted that 1) sex-biased gene expression would increase during ontogeny, 2) these ontogenetic increases in sex-biased expression would differ between tissues, and 3) growth-regulatory gene networks would be more sex-biased in liver and muscle than in brain. We found that sex-biased gene expression increased during development, but that the trajectory of this ontogenetic increase in sex-biased expression varied between tissues. We also found that sex-biased expression of growth genes increased sharply during development in the liver and muscle, but not the brain. Our results confirm that sex-biased gene expression increases throughout ontogeny, but also show that tissue-specific trajectories need to be considered when examining the relationship between sex-biased gene expression and sexual dimorphism.

P3-140 CIERI , RL*; FARMER, CG; University of Utah, University of Utah; Trinity College, Dublin; *bob.cieri@utah.edu*

Investigation of pulmonary airflow patterns in monitor lizards using computational fluid dynamics (Varanidae)

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 comparative physiologists. 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. Computational fluid dynamics, which simulates patterns of flow from prescribed boundary conditions and the laws of fluid motion, 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 monitor lizards, *Varanidae*. The surface of the computational mesh expanded and contracted to simulate lung motion during ventilation and provided the boundary conditions for flow. Simulations were carried out in open-source software on an 80-processor computing cluster. Our model yields unidirectional flow in many regions of the lung and reveals airflow patterns in chambers that are too small or are inaccessible to empirical study. 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.

35-2 CINEL, SD*; KAWAHARA, AY; TAYLOR, SJ; University of Florida, Florida Museum of Natural History, Illinois Natural History Survey; *cinel1@ufl.edu*

Transcriptomic signals of cellular stress in fall armyworm (Spodoptera frugiperda; Lepidoptera: Noctuidae) brain tissue after prolonged auditory exposure to bat calls

Predation risk induces behavioral and physiological responses that have traditionally been considered acute and transitory. However, prolonged or frequent exposure to predators and their cues can impact long-term prey physiology and demographics. For instance, some moths are equipped with tympana that allow the perception of ultrasonic bat calls. Past research indicates some moths experience altered fitness and physiology after exposure to synthetic ultrasound, but the ecological relevance of these findings is not yet understood. Here, we exposed 4 adult male fall armyworm (*Spodoptera frugiperda*; Lepidoptera: Noctuidae) moths to either silence or sporadic recorded ultrasonic bat calls for 8 hrs and then constructed a combined de novo transcriptome based on dissected brain tissue. Using differential expression (DE) and Gene Ontology (GO) enrichment analyses, we identified 305 DE transcripts and 15 overrepresented GO terms in cue-exposed individuals. The annotated DE transcripts represented broad functional protein-coding mRNAs in the brain, including those related to neurotransmitter metabolism, ionotropic receptor expression, mitochondrial metabolism, protein chaperone activity, antioxidant activity, actin cytoskeleton dynamics, chromatin binding, epigenetic methylation, axon guidance, and neural development. The five most overrepresented GO terms included chromatin binding, macromolecular complex binding, glutamate (Glu) synthase activity, Glu metabolic process, and Glu biosynthetic process. As a first assessment of auditory predator cues on transcriptional responses in the brains of moth prey, these results suggest exposure to cues of bat presence alone can influence long-term stress physiology of ‘eared' moth prey.

P3-75 CIRINO, LA*; MOORE, PJ; MILLER, CW; University of Florida, University of Georgia; *lacirino@ufl.edu*
The effect of dynamic diets on female reproductive traits
It is well known that poor early life nutrition has strong negative effects on reproduction. Adult nutrition can also affect reproductive output. Those few studies that have teased apart the effects of nutrition at different life stages on female reproductive output have done so through the use of artificial diets. Because of these artificial diets, it is less clear if animals can overcome poor early life nutrition as they take advantage of higher quality seasonal resources that become available later in life in the wild. To understand how separate and combined natural juvenile and adult nutrition affects female life history traits, we asked: What are the impacts of natural diets on female reproductive traits in leaf-footed cactus bugs? Juveniles were placed on two different cactus pad treatments: ripe fruited cactus pads (optimal) and unripe fruited cactus pads (suboptimal). Upon adulthood, a subset of the suboptimal diet females were placed on optimal diets. Preliminary analyses suggest that suboptimal juvenile nutrition does affect female receptivity with females more likely to mate at a younger adult age even though ovary mass and egg production does not differ between treatments. However, after females age for two weeks on their respective diets, female receptivity increases for all diet treatments and does not differ between them. Further, both optimal diet females and those females switched on to optimal diets in their adulthood appear to have less egg production and ovary mass than the suboptimal diet treatment. These results may represent a life history tradeoff where females allocate their limited resources to reproduction in early adult life due to their poor nutritional environment.

S2-9 CIVITELLO, DJ*; MALISHEV, M; Emory University; *dcivite@emory.edu*
Scaling bioenergetic theory to predict the population dynamics of human schistosomes and intermediate snail hosts
Observations that the outcome of infection for individual hosts depends on ecological factors such as age, sex, resource availability, and environmental stressors form the foundation of ecological immunology. However, it remains challenging to scale individual-level patterns, and their underlying mechanisms, up to the level of populations or ecological communities. Despite this challenge, scaling eco-immunology up to the population and community level could greatly enhance our understanding of the ecological dynamics of disease, feedbacks among parasitism and other ecological interactions, and the eco-epidemiological consequences of anthropogenic impacts and disease control efforts. Here we use Individual Based Models (IBMs) based on general metabolic theory [Dynamic Energy Budget (DEB)] theory to scale from individual infection dynamics (time-explicit life-history trajectories of growth, reproduction, parasite production, and death) to epidemiological dynamics using the major human parasite, Schistosoma mansoni, and its intermediate host snail, Biomphalaria glabrata. At the individual level, low resource supply and/or intense resource competition greatly reduces parasite production by infected snails. At the population level, our DEB-IBM predicts brief, but intense periods of parasite production, and therefore human risk, when resources become abundant, i.e., early in seasonal environments, following pulses of resource enrichment, or after attempts at snail elimination. These more nuanced, individually-based epidemiological predictions can identify specific conditions, times of the year, and periods of elevated risk to better track ecological feedbacks of disease management and improve the prevention of human risk for schistosome infection.

P2-144 CLARDY, TR*; HEINLE, MJ; THOMAS, BK; AL-NUWAIRAH, MA; DAS, PB; QURBAN, MA; HIKMAWAN, TI; PRIHARTATO, PK; ABDULKADER, KA; King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, Environmental Protection Department, Saudi Aramco, Dhahran, Saudi Arabia; *tclardy@kfupm.edu.sa*
Response of zooplankton to a phytoplankton bloom in coastal waters of the Western Arabian Gulf
Phytoplankton blooms can have significant positive or negative effects on the structure and abundance of zooplankton communities. A diatom bloom comprised of *Skeletonema* sp. and *Thalassiosira* sp. was encountered off Khobar, Saudi Arabia. A suite of environmental and biological parameters within the bloom and at a reference site were measured to assess the effect of the bloom on zooplankton. The dominant copepod species at both sites, *Acartia ohtsukai*, showed a 15x reduction inside the bloom. The fitness of individual *A. ohtsukai* inside and outside the bloom was compared using body volume. Measurements of the prosome and urosome from 50 males and 50 females from each location were made to calculate the body volume of individual copepods. There were no significant differences in copepod volume between sites for either sex, indicating the bloom was not affecting the fitness of individual copepods. Both *Skeletonema* and *Thalassiosira* produce aldehydes that compromise embryonic development in copepod eggs. The reduction in zooplankton density associated with the bloom was likely a result of population-level effects on reproduction rather than a reduction in individual fitness.

P2-103 CLAUNCH, NM*; SCHOENLE, LA; OAKEY, S; DOWNES, C; MARTIN, LB; ROMAGOSA, CM; REED, RN; University of Florida, Hamilton College , University of South Florida, University of South Florida, Hamilton College, University of South Florida, United States Geological Survey, Invasive Species Branch; *nmclaunch@ufl.edu*
Stress responses of an infamous island invader, Boiga irregularis
The insular population of introduced brown tree snakes (*Boiga irregularis*) on Guam have largely depleted the native vertebrate fauna, yet continue to exist at relatively high densities. Under such conditions of stress, secretion of the glucocorticoid hormones may be altered, which can subsequently affect fitness. This well-studied population of snakes provides an avenue for long-term evaluation of glucocorticoid responses, and an opportunity to examine functional aspects of changes in corticosterone (CORT), such as innate immunity. In April 2018 we captured 37 brown tree snakes and collected baseline blood samples in under 7 minutes. Snakes were placed in cloth bags for one hour to induce an acute stress response and resampled. All blood was immediately centrifuged, serum separated, and flash-frozen in liquid nitrogen vapor phase, then transferred to a freezer at -80 C on return to the mainland. Bacterial-killing ability was assessed within 1 month of collection. We assessed percent killing ability of plasma incubated with *E. coli* and compared it to growth of *E. coli* in a positive control via spectophotometry. CORT concentration was assessed via enzyme immunoassay with a commercially-available kit. We evaluate the hypothesis that glucocorticoid hormone levels are altered over time in populations with depleted resources and overpopulation by comparing our data to data collected 15 and 25 years prior. Additionally, we examine the functional response of the complement pathway of the innate immune system via bacterial-killing ability of plasma as it relates to baseline and acutely-stressed CORT levels.

P2-274 CLEGG, DC*; CHI, RC; REITZEL, AM; Univ. of North Carolina, Charlotte; *dclegg1@uncc.edu*
Characterization and Expression of Transcription Factors in the Circadian Clock of Cnidarians
Transcription factors regulate expression of the genome through specific binding to particular sequence motifs as well as protein-protein interactions. Members of the bZIP and bHLH-PAS families of transcription factors have roles in diverse molecular processes, including the circadian clock and antioxidant response for many animals. Although comparative genomics has shown these gene families are present and diverse in cnidarians, we currently know little about the shared and unique functions for particular bZIP and bHLH-PAS proteins in this phylum. Here, we report on our studies of the expression and binding preferences for bZIP protein in the PAR family and bHLH-PAS proteins related to the circadian clock from the sea anemone *Nematostella vectensis*. We have successfully cloned and optimized expression for seven of these transcription factors as bacterial recombinant GST fusion proteins. We will also describe results from ongoing approaches to determine the diversity of DNA binding motifs for each protein. Results from these assays will aid in determining potential target genes for these transcription factors and how the expression of these genes varies over a diel lighting period.

128-1 CLIFTON, GT*; HOLWAY, D; GRAVISH, N; Univ. of California, San Diego, UCSD; *glclifton@eng.ucsd.edu*
Large-scale, Automated Tracking of Ant Walking Reveals Kinematic Mechanisms Underlying Speed Constraints on Uneven Ground
Ants walk long distances to find food and defend territories. Yet, the substrates they experience are typically rugged and uneven, potentially challenging locomotion performance. Because ant walking speed and energetics have significant ecological and evolutionary implications, ants are a useful system to study kinematic modulation on rough ground. Here we combine laboratory studies of walking kinematics with ecologically-relevant field preference experiments to understand how walking patterns and preferences vary with substrate. A custom automated camera system recorded over 8000 high-speed videos of Argentine ants (*Linepithema humile*) walking on 3D-printed substrates with a checkerboard pattern of varying step width (1, 3 and 5 mm, 1 mm step height). Although ants on rough substrates could occasionally reach the faster speeds observed on flat ground, they demonstrated a strong speed constraint while walking on rough substrates, particularly those with checkerboard widths smaller than their 3-4 mm body length (median speed decreased by 21%, 20%, and 12% on 1, 3, and 5 mm respectively compared to flat ground). An automated, deep-learning method tracked limb kinematics during >210,000 strides, revealing that rough substrates both increased variability in foot placement (by 60, 70, and 44% respectively compared to flat ground) and shifted the proportion of disrupted strides (from 5% on flat ground to 24%, 18%, and 12% on 1, 3, and 5 mm substrates). This study represents a highly-detailed investigation of ant locomotion and limb kinematics on uneven ground. Our findings have the potential to explain observed ecological patterns, inform conservation guidelines, and inspire new robotic control strategies.

125-5 CLISSOLD, FJ*; WOODMAN, JD; WILSON, K; SIMPSON, SJ; The University of Sydney, Department of Agriculture and Water Resources, Lancaster University; *fiona.clissold@sydney.edu.au*
The influence of temperature on nutrient supply and demand: host plant quality is temperature dependent
Population dynamics of herbivorous insects are strongly correlated with climate, largely through the influence of temperature on physiological processes and rainfall on food quality. Using Australian plague locusts, we have quantified diet quality across its temperature range. Rates of development are most influenced by temperature, and growth by diet. The slowest developing and smallest insects occurred when feeding on diets high in carbohydrate and low in protein, and when ingestion rates were most reduced. While diet quality at any given temperature can be quantified using chemically defined foods, measuring the chemical composition of leaves does not provide an indication of the quality of that leaf to an insect herbivore. From a range of native and improved pasture grasses we found the rate protein and carbohydrate were supplied, varied independently and non-linearly with temperature. Typically, Australian plague locusts were able to gain an optimal ratio of protein to carbohydrate at their thermal optima because at this temperature protein was extracted with lowest efficiency but carbohydrate with highest efficiency. However, the rates of supply of all nutrients scaled in a plant specific manner with temperature. Thus, host plant quality is temperature dependent, or conversely, dietary fitness is optimized at a specific temperature for a given plant. These results highlight the complexity of ecological interactions. For highly mobile insects such as locusts, what may appear to be a nutritional complex environment may not be, if there is thermal heterogeneity.

39-1 CLISSOLD, FJ*; WOODMAN, JD; WILSON, K; SIMPSON, SJ; The University of Sydney, Department of Agriculture and Water Resources, Lancaster University; *fiona.clissold@sydney.edu.au*
The interactive impact of temperature and nutrition on disease resistance
Temperature and nutrition influence the growth and development of all organisms, with the interaction between insects and their diseases being very complex. For locusts, body temperature influences their rate of development along with the nutritional resources extracted from their host plants (through differential digestion) and the growth rates of any microbes or pathogens they harbor. We quantified the growth and development the Australian plague locust and the fungus *Metarhizium anisopliae* var. acridum, across a range of temperatures and diets. Heat maps demonstrated the thermal and nutritional optima's for both the locust and the fungus differ significantly, with a little overlap. At constant temperatures the locust can only complete its life cycle between 26-44 ^{o}C with growth being fastest and heaviest at 41 ^{o}C on a slightly carbohydrate biased diet, while the fungus grows fastest at 26 ^{o}C on a protein-biased diet, with no detectable growth below 15 or above 35 ^{o}C. However, the fungus is able to ‘kill' its host as it can withstand both high and low temperatures for at least a month and when returned to its temperature optima, is able to grow. Thus, the fungus survives due to daily temperature fluctuations, which it exploits, eventually overwhelming the locust.

P2-179 COFFIN, JL*; KELLEY, JL; JEYASINGH, PD; TOBLER, M; Kansas State University, Washington State University, Oklahoma State University; *jlcoffin3@gmail.com*

Responses of Fishes to Heavy Metal Contaminated Extreme Environments

Heavy metal pollution stemming from mining activities has profound biological effects, causing reproductive damage, behavioral changes, and increased mortality on an individual level, with cascading consequences for populations and ecosystems. The Tar Creek Superfund site in the Tri-State Mining District of Kansas, Missouri, and Oklahoma was declared due to heavy metal pollution from acidic mine runoff in the Tar Creek watershed. Resident populations of Western mosquitofish (*Gambusia affinis*) provide an opportunity to study organismal and evolutionary responses to heavy metal pollution at all levels of organization. Mosquitofish are the dominant species in polluted sections of Tar Creek and also occur in numerous proximate, uncontaminated watersheds, facilitating comparative analyses. We used high-throughput elemental profiling and RNA-sequencing in gill, liver, and brain tissues to address basic questions about organismal responses to heavy metal stress: 1) how does the extent of metal accumulation vary across tissues in *G. affinis*?; 2) how does metal accumulation differ between contaminated and uncontaminated populations of *G. affinis*?; and 3) what genes are differentially expressed between contaminated and uncontaminated populations? Future work will discern whether these observed gene expression differences are due to evolution or plasticity, which will allow us to investigate how heavy metal pollution might impact rapid evolutionary responses and understand the mechanisms that have allowed *G. affinis* to inhabit extreme environments.

P2-259 COHEN, KE*; ACKLES , AL; HERNANDEZ, LP; University of Washington , Michigan State University , The George Washington University ; *kecohen@uw.edu*

Origin, heterochrony, and diversification of otocephalan epibranchial organs

Epibranchial organs are paired food-aggregating structures thought to have evolved at least six times within actinopterygian fishes. Ranging in complexity from small slits on the ventral pharyngeal roof to complex spiraling structures, epibranchial organs are morphologically diverse. Despite this morphological diversity and broad distribution, little is known of the development and evolution of epibranchial organs. Here we investigate the origin of the epibranchial organ by comparing ontogeny within three different species. Anchoa mitchilli (Engraulidae) represents a more basal species with a simple epibranchial organ, Brevoortia tyrannus (Clupeidae) has a more anatomically complex epibranchial organ, and Hypophthalmichthys molitrix (Cyprinidae) represents the most complex epibranchial organ described. Despite the final adult morphology all epibranchial organs initially develop from an epithelial involution that is subsequently surrounded by muscle dorsal to the fourth and fifth pharyngeal arches. The epibranchials and infrapharyngeobranchials are hypertrophied to support the growing structure. There was a strong correlation between ossification rates of the branchial arches and the development and overall size of the epibranchial organ. Thus, in H. molitrix the fourth and fifth arches develop and ossify before the more anterior arches. The final structure is composed of all five arches whereas in both Brevoortia and Anchoa ossification of the arches begins later in development and only the fourth and/or fifth arches are included in the epibranchial organ. We hypothesize that the epibranchial organ originated from an involution into the pharyngeal tissue supported by a modified posterior branchial arch.

32-5 COHEN, KC*; WELLER, HI; SUMMERS, AP; University of Washington , Brown University ; *kecohen@uw.edu*

Getting to the tooth of the matter: a statistical test for functional homodonty

Teeth tell a story of the interaction between predator and prey. If the teeth in a jaw look the ‘same' we call them homodont; and if there is distinct regional specialization in size or shape they are heterodont. These are vague terms with no useful functional implication. Tooth shape affects function and has been explicitly tested and modeled - conical teeth are good for piercing, molariform teeth for crushing, and serrated teeth cut well. We are interested in the concept of homodonty and the conical tooth. There is a great deal of variation in the shape and placement of conical teeth. Anterior teeth may be larger than posterior ones, larger teeth may be surrounded by small ones, and patches of teeth may all have the same size and shape. We consider the pressure that a tooth can exert on prey; as often pressure is what leads to prey failure. We can calculate pressure from surface area and the distance a given tooth is along the jaw. Functional homodonty is then defined as all the teeth along the jaw bearing/exerting similar stress values despite position. We find conical teeth are functionally homodont when larger teeth are surrounded by smaller teeth. Suggesting a functional advantage to having a number of smaller teeth surrounding a singular large tooth. We hypothesize this tooth placement may allow an individual to grab prey upon puncture, rather than tear through and that smaller teeth quickly dissipate large stress forces away from the larger tooth. However, what constrains this system, as there is not an unlimited amount of teeth that can exist along the jaw. Moreover, teeth at the back of the jaw have little effect on the performance of teeth at the front of the jaw. We hypothesize that there is an optimal distance and surface area of smaller conical teeth in relation to larger teeth in functionally homodont dentition.

P3-32 COHEN, HE*; KANE, EA; Georgia Southern University; *hc02684@georgiasouthern.edu*

Damaged Goods: Do Injuries Affect Swimming Performance During Prey Capture in Bluegill?

Many animals must use some sort of locomotion in order to survive. However, injuries from predators, intraspecific attacks, and disease can affect locomotor performance. In fish, fins are used to swim and maneuver during behaviors such as catching prey, avoiding predation, and finding mates. An injury to their fins can potentially affect their ability to perform these behaviors and even cause mortality. Bluegill sunfish (*Lepomis macrochirus*) are a common freshwater species in North America, have been a model organism for performance studies, and often experience natural injuries. We investigate the effects of fin damage on swimming performance during prey capture in bluegill. We hypothesize that fish with injured fins will show a decrease in performance traits. Individuals were caught from a local hatchery where differences in capture technique resulted in fish with either healthy or damaged fins. Bluegill were recorded with a high speed camera at 500 fps while they captured prey. We predict that approach velocity and acceleration will be slower, predator-prey distance will be shorter, and time to prey capture will be longer in fish with damaged fins. These differences can have consequences for competing for food and capturing evasive prey. If differences aren't apparent, it may indicate that fish might compensate by using other fins.

P2-51 COLAVITA, M*; WITHERELL, H; ERICKSON, J; SCHREIBER, W; University of Louisville, Washington and Lee University; *colavitam18@mail.wlu.edu*

Measurement of Discrete Behaviors in Ants Using Spatially-Averaged Intensity Gradients

Animal behavior research often requires the capture and subsequent analysis of behavior recorded from live organisms. Quantifying the expression of behavior (especially in insects) can be challenging when using human observers alone. The purpose of this project was to develop a computer-automated analysis method for discrete behaviors (measured qualitatively) in ants which would yield a high level of coherence with the evaluations of a separate human observer. We were specifically interested in examining the expression of forward antennal movements in a sample of animal data (n = 4; 25 observations/animal) collected from a previous, unpublished study. Western harvester ants harnessed in a modified 100 µL pipette tip were exposed to a total of twenty-five presentations of an odorant stimulus and/or untreated cotton-tipped applicator. Forward movements of the antenna during stimulus presentations were scored as a binary outcome (yes/no) by a blind researcher. Videos were analyzed in MATLAB by defining a region of interest and measuring the spatially-averaged intensity and spatially-averaged intensity gradient for each frame of the video file. Threshold values were set to a multiple (1, 2, 3, 4, and 5x) of the noise level, which was computed using the median of the absolute deviation, and the expression of forward movement was determined by whether a measurement during the period of stimulus presentation exceeded the threshold value. Overall, this automated method yielded high levels agreement (μ = 85%) and inter-rater reliability with a human observer at low thresholds, but lower levels of agreement and inter-rater reliability at threshold values of 3 or more. This automated method will help accelerate rapid and accurate analysis of ant behavior in future studies.

126-5 COLE, JM*; VAN BELLEGHEM, SM; COUNTERMAN, BA; Mississippi State University, Starkville, MS, University of Cambridge, Cambridge, UK; *jmc675@msstate.edu*

The influence of demographic history on heterogeneous patterns of genomic divergence in an incipient Heliconius species

Identifying the forces responsible for driving genomic divergence between incipient species remains a challenging but central area of research in evolutionary biology. Such forces can include divergent natural selection, but also the historical demography of interacting populations. Population size changes and variable migration rates can lead to the accumulation of heterogeneous genomic differences between populations despite the absence of selection. Thus, a major goal in speciation genomics research is to disentangle these forces by modeling the demographic history. Populations of the neotropical butterfly genus *Heliconius* provide an ideal system to study the effects of population demography during divergence. *Heliconius himera* is considered an incipient species within the *Heliconius erato* clade that displays increased genome-wide levels of divergence with neighboring *H. erato* populations. Here, we use diffusion simulations to model the demographic scenarios that could potentially impact patterns of genomic divergence between hybridizing incipient species *H. erato* and *H. himera*. Demographic modeling shows that both species experienced bottlenecks in their recent histories, followed by limited expansion in *H. himera* and much larger expansion on *H. erato*. Models of species divergence supported a period of isolation between the species, followed by secondary contact with *H. erato* populations west of the Andes. Further analysis showed there was an excess of introgression from *H. erato* in the *H. himera* population. These results highlight the importance of demographic history in shaping heterogeneous patterns of genomic divergence between hybridizing species.

66-7 COLEMAN, A; SCOTT, DE; CAPPS, KA; PARK, AW; LANCE, SL*; Univ. of Georgia; *lance@srel.uga.edu*

Environmental Factors Outweigh Community Ecology in Ranavirus Transmission

Understanding how biodiversity influences pathogen occurrence has global implications for predicting disease outbreaks and preventing additional biodiversity loss. The dilution effect hypothesis suggests that more diverse communities constrain pathogen spread through several mechanisms and recent meta-analyses suggest that the dilution effect is common. However, few studies of diversity-disease relationships have addressed the role of physiochemical properties that can influence community assembly and affect host and pathogen physiology. We used a system characterized by a multi-host pathogen, Ranavirus (RV), and complex assemblages of amphibians residing in ephemeral wetlands to quantify the relative contributions of biotic and abiotic factors on infection risk. We characterized the amphibian communities for 20 ephemeral wetlands and investigated the relationship between amphibian communities and ranavirus prevalence. We captured over 30,000 individual amphibians representing 23 species and quantified presence of ranavirus in a subset. Ranavirus prevalence varied significantly across species and wetlands. Based on boosted regression tree analyses, environmental variables including canopy cover and water and air temperature are the most important factors driving ranavirus occurrence. We saw no evidence of a dilution effect and no measure related to community ecology had a relative influence greater than 5%. Numerous factors related to abundances of species each had low relative influence and their combined influence suggests a role for community ecology in ranavirus dynamics. Still, the influence of environmental factors appears to be more important in determining patterns of ranavirus infection on the landscape.

P1-65 COLLAR, DC*; TREMAINE, S; HARRINGTON, RC; FRIEDMAN, M; Christopher Newport University, Yale University, University of Michigan; *david.collar@cnu.edu*

The Adaptive Landscape for Body Shape and Its Anatomical Determinants in Pelagiarian Fishes

Body elongation is one of the most prominent aspects of morphological diversification in fishes. Evolutionary transitions between disc-shaped, fusiform, and eel-like bodies involve some combination of changes to head shape or vertebral dimensions, but it is unknown whether major shifts in body shape require particular suites of anatomical changes. In this study, we investigate the evolutionary origins of the remarkable diversity of body shape within Pelagiaria—a radiation of open-ocean fishes containing 15 recognized families that span much of the range of body shapes exhibited among ray-finned fishes. Using a robust fossil-calibrated molecular phylogeny and a Bayesian method for estimating the adaptive landscape, we identify shifts in optima for overall body shape and for the anatomical components that determine it. We estimate a relatively deep-bodied pelagiarian ancestor, a shift to a fusiform optimum that is widely shared among lineages (e.g., tunas and mackerels, bluefish), and several transitions to elongated forms. One of these transitions—the one leading to the highly elongated Trichiuridae (e.g. cutlassfishes)—is associated with shifts in optima for most underlying anatomical components (i.e., lengthening of the head and abdominal and caudal vertebral regions). Other instances of body elongation, however, are associated with peak shifts for different subsets of anatomical components, revealing a mosaic of adaptive landscapes for the parts of the body that drive body shape diversification in Pelagiaria.

P1-194 COLLINS, M/G*; HULSEY, R/D; SMITH, K/M; CHILDRESS, M/J; Clemson University, Clemson University ; *mgcolli@g.clemson.edu*

A Tail of Two Territories: Sex Differences in the Territories of Stoplight Parrotfish, Sparisoma viride

Parrotfish are abundant herbivores that inhabit the coral reefs located in the Florida Keys. These herbivores have major impacts on coral reef ecosystems by regulating the abundance of competitive algae and indirectly benefitting corals. These hermaphroditic fish have a social structure in which one terminal phase male controls and protects a territory. Previous studies have shown that territory size may be determined by harem size (female defense polygyny) or, dietary preferences and reef complexity (resource defense polygyny). Our study tests which hypothesis best explains territory size in terminal and initial phase stoplight parrotfish (*Sparisoma viride*) on reefs located in the middle Florida Keys National Marine Sanctuary. We followed two terminal parrotfish and two initial parrotfish on four sites for ten minutes, estimating territory size by dropping markers. We also measured substrate cover, rugosity and conspecific density for each territory. Our results show that terminal phase parrotfish have significantly larger territories than intermediate parrotfish and intermediate phase territories only overlap the edges of terminal fish territories. We also found that terminal phase territory size was negatively correlated with conspecific density. These results suggest territory size among terminal phase stoplight parrotfish may be focused towards female defense polygyny, where territories are driven by the presence of a harem.

50-1 COLLINS, EE*; HALANYCH, KM; MAHON, AR; Central Michigan Univ., Auburn Univ.; *eecollin1@gmail.com*

Phylogeny of sea spider (Arthropoda, Pycnogonida) families determined with mitochondrial genomes

Globally distributed pycnogonids, sea spiders, are a speciose chelicerate clade with 10 putative extant families. There is general agreement concerning both morphology and molecular data that sea spiders are within chelicerate Arthropods. Evolutionary patterns within Pycnogonida, particularly between families, remain unresolved due to unique morphological traits and highly reduced forms. To date, the relationships between pycnogonid clades is poorly understood and a consensus on phylogeny within the group is lacking. There have been two previous studies, which produced contrasting topologies for interrelationships between pycnogonid families. One study used morphological characteristics and six molecular loci, whereas the other was based solely on 18S rRNA sequence data. To further resolve evolutionary relationships between major groups of sea spiders, we sequenced 13 mitochondrial genomes, representing most recognized sea spider families to reconstruct phylogenetic relationships. This effort included 10 groups not previously sequenced and greatly increased the available mtDNA genome data for pycnogonids. Bayesian inference based on amino acid sequences of protein coding genes indicated that all recognized families with more than one individual represented were monophyletic. The order of protein coding genes is consistent between all sea spider mitogenomes except for *Nymphon gracile*. Rearrangement is more common in tRNA coding sequences and occurs in six individuals from for families in this dataset. Monophyly of all individuals from the same family and high posterior probabilities for all clades support the use of mitochondrial genomes for detection of sea spider phylogenetic position at the family level.

4-2 COLOMBARA, A.M.*; CHADWICK, N.E.; Auburn University; *amc0119@tigermail.auburn.edu*

Impact of thermal stressors on growth and physiology of the tropical sea anemone Bartholomea annulata

Thermal stress driven by anthropogenic CO_2 emissions can cause often lethal thermal stress to organisms in marine environments. Determining effects of thermal stress in tropical reef organisms is vital because coral reefs represent the most biodiverse and economically valuable marine ecosystems. Corkscrew sea anemones *Bartholomea annulata* form complex symbiotic relationships on Caribbean reefs, creating mutualistic cleaning networks that enhance reef fish diversity. We examined effects of thermal stress on host polyp growth and respiration, and on the abundance and photosynthetic rate of endosymbiotic microalgae in corkscrew anemones. Our results indicate that elevated seawater temperature (32°C) causes a significant decline in both host anemone body size and microalgal abundance within the host (bleaching), but an increase in chlorophyll concentration in the remaining microalgal cells. Anemones grow maximally at optimal coral reef temperatures of ~22-25°C, but relatively low temperature (18°C) also decreases anemone body size and microalgal abundance. The physiological mechanisms underlying these changes may involve a complex interplay between metabolic processes, in that temperature extremes significantly reduce photosynthetic rate whereas temperature increases significantly enhance respiration rate. These data have important implications for understanding physiological processes under stress in non-calcifying cnidarians, for application to coral reef conservation management under future climate change scenarios.

62-7 COLSTON, TJ*; UL-HASAN, S; Florida State University, University of California, Merced; *tim@maddreptiles.com*

iVAMP: An Initiative for Studying the Venom-Associated Microbiome and Its Biological Significance

Approximately 15% of Earth's animal biodiversity produce toxins delivered through a mechanical feature for prey capture and/or defense. Collectively referred to as venoms, these toxins and their sophisticated delivery have convergently evolved between vastly different taxonomic groups. Due to (i) the pharmacological potential of these toxins and (ii) human health concerns presented by certain taxa (e.g. venomous snakes and spiders), efforts to understand the evolutionary processes underlying the diversification of venomous organisms and the functional aspects of their venom have expanded. Advances in next-generation sequencing technologies make the acquisition of genomic, transcriptomic, and proteomic information more feasible as part of these efforts and provide the key to unlocking a wealth of knowledge not only on venomous animals, but also their associated "microbiome." Despite the parallel advances of these fields as an outcome of utilizing NGS, a disconnect between Venomics and Host-Associated Microbiomes persists. Most overlapping studies identify anti-microbial components in venom, with little investigation of microbial interactions in the specialized glands or venom. These studies either focus on easily culturable species or exclude the wildtype microbial community as a control. We thus present the current knowledge of the microbial diversity known to be associated with venom as an introduction to our interdisciplinary group of more than 25 researchers worldwide that are currently working to establish high-throughput pipelines, standardized methodologies, and an open-source platform for all interested in studying the biological significance of the venom microbiome.

104-4 COMBES, SA*; BADGER, MA; GAGLIARDI, SF; WARGIN, AH; FLORES, MS; Univ. of California, Davis; *sacombes@ucdavis.edu*

Inferring real-world flight conditions from high-throughput preference tests: bumblebees display partiality for particular features of wind and clutter

Foraging bumblebees regularly fly through environments filled with varying wind and clutter. In lab settings we can impose challenging flight conditions, but whether wild bees choose to avoid some conditions by altering their routes through natural habitats remains unknown. We performed a series of automated, high-throughput choice experiments, in which colonies of *Bombus impatiens* could forage for nectar at the end of a dual-channel tunnel. The tunnel had small fans to induce flow in each channel independently, as well as removable obstacle fields containing arrays of either small (1/4-inch diameter) or large (1-inch diameter) vertical posts staggered to induce maneuvering, with equal minimum gap distances between obstacles. We altered conditions in the two channels and collected 120 short video segments each day. We tested whether bees display a preference for flying through large vs. small obstacles, and whether the presence or direction of wind alters this preference. We used an automated program to identify and track bees in videos, yielding more than 15,000 tracked flights. Bees exhibited a consistent preference for flying between small obstacles as opposed to large ones, despite this requiring them to pass through more obstacles. This preference could be overturned, however, based on the direction of wind: bees displayed a strong preference for flying upwind or through still air as opposed to flying downwind, regardless of the type of clutter present. Taken together, these results suggest that a variety of factors, including the direction of air flow and the size scale of clutter may affect microhabitat use and determine the flight conditions actually experienced by wild bees.

38-6 CONITH, AJ*; LAM, DT; ALBERTSON, RC; Univ. of Massachusetts Amherst; *ajconith@bio.umass.edu*

Muscle-Induced Loading as a Major Source of Variation in Craniofacial Skeletal Shape

The shape of the craniofacial skeleton is constantly changing through ontogeny, and reflects a balance between developmental patterning and mechanical-load induced remodeling. Muscles are a major contributor to producing the mechanical environment that is crucial for "normal" skull development. Here we use an F5 hybrid population of Lake Malawi cichlids to characterize the strength and types of associations between craniofacial bones and muscles. We focus on four bones/bone complexes, with different developmental origins, alongside four muscles with distinct functions. We use micro-computed tomography to extract 3D information on bones and muscles. 3D geometric morphometrics and volumetric measurements were used to characterize bone and muscle shape, respectively. Linear regressions were then performed to test for associations between bone shape and muscle volume. We identified three types of associations between muscles and bones: weak, strong direct (i.e., muscles insert directly onto bone), and strong indirect (i.e., bone is influenced by muscles without a direct connection). In addition, we show that whereas the shape of some bones are relatively robust to muscle-induced mechanical stimulus, others appear to be highly sensitive to muscular input, both direct and indirect. Our results imply that the roles for muscular input on skeletal shape extend beyond specific points of origin or insertion, and hold significant potential to influence broader patterns of craniofacial geometry. Thus, changes in the loading environment, either as a normal course of ontogeny or if an organism is exposed to a novel environment, may have pronounced and unexpected effects on skeletal shape.

AMS-1 CONN, David-Bruce; Berry College, Mount Berry, GA and Harvard University, Cambridge, MA; *bconn@berry.edu*

Functional Morphology Meets Infectious Disease Epidemiology: How Parasitic Flatworms Move Between and Within Hosts

The emerging integrative field of One Health science departs from traditional focus on disease as malady and conceptualizes infection as natural organismal and ecological process. Our research over 3 decades has utilized electron, light and confocal microscopy to examine reproduction and development of parasitic worms that constitute strategies for dispersal in the environment between hosts and optimize targeted colonization of specific sites within hosts. Studying cestodes and trematodes from basal to highly derived taxa, we have demonstrated wide variation in structural and developmental strategies that facilitate dispersal and colonization. These range from specialized embryonic and larval structures to highly plastic morphogenesis of both reproductive and somatic systems. Our newest results analyzed in this synthetic review include: embryonic structures of *Gyrocotyle urna* (from European marine fish); embryonic and larval structures of 4 microphalloid digenean species (from Eurasian frogs); uterine and extrauterine structures of *Thysanotaenia congolensis* (from African rodents); serial multistage larval structures of *Ornithodiplostomum ptychocheilus* (from North American freshwater fish); aberrant neoplastic structures of *Hymenolepis nana* (juveniles/adults from humans) and *Mesocestoides* and *Spirometra* (juveniles from mammals, birds, reptiles and amphibians on 6 continents). The latter are examples of malignant transformation (cancer) in invertebrates, which becomes highly pathogenic and ultimately deadly to the host as the parasite becomes uncontrollably invasive. Taken together, these examples demonstrate remarkable evolutionary and developmental plasticity among flatworms that have undertaken infection of vertebrate hosts as a life strategy.

P1-200 CONNELLY, M. T. *; MCRAE, C.; LIU, P. J. ; TRAYLOR-KNOWLES, N.; University of Miami, National Dong-Hwa University; *mconnelly@rsmas.miami.edu*

Patterns of Pocillopora damicornis immune gene expression in response to antibiotics treatment, heat stress, and immune stimulation with bacterial lipopolysaccharide

Reef-building corals establish diverse symbioses with dinoflagellates, bacteria, and micro-eukaryotes that benefit the health of the coral holobiont. Climate change is causing a collapse of coral reef ecosystems, as high sea surface temperatures disrupt the stability of coral symbioses to cause coral bleaching, disease and death. Activation of coral innate immunity has been observed during coral stress responses, which may also be affected by coral bacterial community composition. To disentangle patterns of immune gene expression driven by heat stress and bacterial community disruption, *Pocillopora damicornis* corals from Kenting National Park in Taiwan were subjected to multiple treatments with antibiotics (ampicillin and streptomycin), heat stress, and immune stimulation with bacterial lipopolysaccharide (LPS). Upregulation of genes involved in immune signaling pathways were observed in treatments with antibiotics and LPS, suggesting that antibiotics treatment causes a dysbiosis in the coral bacterial community that drives inflammation. Weighted gene co-expression network analysis also revealed numerous co-expressed gene modules that were significantly correlated to treatment conditions. Several modules were positively correlated to LPS treatment and negatively correlated to heat stress, and were also enriched in genes related to innate immunity such as Toll-like receptors (TLRs), c-Jun N-terminal kinase (JNK) and mitogen-activated protein kinase (MAPK) pathways. These results corroborate reports of coral immune suppression during heat stress and suggest that stability in the coral bacterial microbiome is essential for coral immune function and homeostasis under future climate scenarios.

20-6 CONNORS, PK*; LIGHT, JE; TANIS, BP; DREW, JA; ANDERSON, CN; HINDE, K; Univ. of Utah, Salt Lake City, Texas A&M Univ., College Station, Oregon State Univ., Corvallis, Columbia Univ., New York, Dominican Univ., River Forest, Arizona State Univ., Tempe; *patrice.kurnath@utah.edu*
March Mammal Madness: a Story about Science and Social Media
Since 2013, the blog "Mammals Suck… Milk" has featured a virtual combat competition among 65 species of animals in a virtual tournament called March Mammal Madness, in honor of the NCAA College Basketball March Madness Championship Tournament. The competition started as a thought experiment among colleagues and has become a pedagogical innovation that engages people from around the globe by creatively integrating scientific literature, original artwork, and digital technologies. Briefly, the winners of simulated animal battles are determined by a probabilistic function of the two species' attributes within a preselected or randomized habitat. Scientific literature is cited to substantiate likely outcomes should the two species encounter one another. Battles are "live-tweeted" by a team of scientists and battle summaries are available afterwards through various virtual media, including Facebook and a library guide created by Arizona State University. Throughout the multi-week competition, participants learn about biological concepts including inter-species interactions, how natural selection has shaped adaptations, conservation management, and the significance of both arts and sciences in education. Here, we summarize the success of the latest championship (#2018MMM) by estimating the potential impact of broadcasting research through social media and classrooms, and by sharing reactions from participants. Our estimates strongly suggest that more people are participating in the championship every year, likely promoting one goal of the competition to inspire awe for the natural world.

P1-154 COONFIELD, A.J.*; IYENGAR, V.K.; Villanova University; *acoonfie@villanova.edu*
Neighbors, Rivals, and Frenemies: Social Networks in the Maritime Earwig, Anisolabis maritima
The spatial distribution of conspecifics can provide important insights into aggression and competition in social species, particularly those in which both sexes possess weaponry. The maritime earwig (*Anisolabis maritima*) lives in high densities under beach debris in coastal ecosystems, and both sexes are aggressive yet differ drastically in both forceps morphology and temperament. Previous research showed that the differential behavior of the sexes affect the spatial distribution of small confined groups—females exhibit more hostile, territorial behavior than males, who tend to interact with one another more frequently—but interactions in more natural arrangements of free-moving individuals had not yet been examined. Given its natural history, the maritime earwig is well-suited for social network analyses, where the movement and proximity of individuals can be tracked to determine how complex interactions within and between the sexes influence social and reproductive behavior. In this study, we ran 30 trials of eighteen marked male and female earwigs collected from San Juan Island, WA, where half the groups had a 2:1 ratio of females to males and half the groups had a 1:1 sex ratio. Each arena contained four possible wood shelters, and we photographed the dispersion of individuals beneath them twice daily for 7 days. By tracking their positions and cohabitation patterns, we mapped social networks to analyze degrees of centrality and cliquishness within each group. We here report that the size and sex of individuals affected their social position and the nature of their connections within the group. Additionally, alteration of the sex ratio, and therefore the social environment, affected the social networks and overall group dynamics.

P1-158 CORDERO, C*; AMBROSE, A; ORTIZ, C; PETANIDOU, T; TSCHEULIN, T; GIRAY, T; HRANITZ, J; BARTHELL, J; GONZALEZ, V; AGOSTO, J; UPR, SSU, Univ. of the Aegean, BU, UCO, KU; *claudia.cordero2@upr.edu*
The response of circadian rhythms to humidity/temperature oscillations and the foraging patterns of specialist and generalist sweat bees
Plant-pollinator interactions are fundamental for conservation biology, agriculture, and ecology. The temporal synchrony between plants and their pollinators is a key aspect of their interaction. However, the specific factors that determine the synchrony between the timing of bee foraging activity and the timing of plant resource availability are not well understood. Biological clocks play an essential role in controlling physiological process in both pollinators and plants. We hypothesize that the temporal pattern of foraging behavior is mainly determined by the interaction between biological clocks and environmental factors such as light, temperature, and humidity, and also these interactions vary among specialist and generalist species. To test the hypothesis, we analyzed the locomotor activity of bees as an index of foraging activity under simulated light, temperature, and humidity oscillations. We conducted the experiment with the generalist social bee L. malachurum and the solitary specialist S. curvicornis. Overall, we found that the two species have different activity patterns: a unimodal pattern for S. curvicornis and a bimodal pattern for L. malachurum. In the case of S. curvicornis, we found that their internal clock run faster than 24 hours and that temperature and/or humidity reset the internal clock in a daily manner. In the case of L. malachurum we found that the bimodality of its pattern is intrinsically driven by the biological clock. Further studies are needed to dissociate the specific contribution of these environmental factors on the activity pattern of these species. This work was supported by the following grants: NSF-REU #1560389, NSF-PIRE #1545803, NSF-PRCEN #1736019, NSF-BigData #1633164 and #1633184, and NSF-PR-LSAMP #1400868.

46-5 CORN, KA*; MARTINEZ, CM; WAINWRIGHT, PC; Univ. of California, Davis; *kacorn@ucdavis.edu*
Feeding mode and prey type affect cranial mobility in coral reef fishes
Skull mobility, including the iconic ability to protrude the upper jaw, is a classic feature of teleost feeding systems. However, the broader relationship between cranial mobility and the many strategies teleost fishes use to capture their prey is unclear. Coral reef fishes show exceptional trophic diversity, ranging from algal scraping in parrotfishes to hyper-extended suction of invertebrates in slingjaw wrasses, and thus make an excellent system to explore how feeding ecology has affected the evolution of cranial mobility. We assembled a dataset from high speed video recordings of suction feeding strikes in 34 species of coral reef fishes that span a range of reliance on suction to biting. We used landmark morphometrics to quantify cranial kinesis as a trajectory of skull shape change during the feeding strike from the initial closed mouth to maximum gape. Species that rely on biting have consistently lower kinesis than habitual suction feeders. Among suction feeders, we find differentiation between suction strikes characterized by high buccal expansion, commonly piscivores, and those characterized by high jaw protrusion, commonly zooplanktivores, indicating that the challenges specific to feeding on different prey can lead to modifications to the mobility of different components of the feeding apparatus. In contrast, most fishes that primarily rely on biting in their natural feeding behavior show low levels of kinesis, which may reflect adaptations that result in enhanced stability of jaw elements for force transmission and loss of skeletal mobility. Overall, we find evidence for reduced kinesis in fishes that rely on biting and that among suction feeders, prey type may affect evolution of skull mobility.

P2-181 CORNELIUS, JM*; CAMERON, R; Eastern Michigan University; *jcornel7@emich.edu*

An experimental investigation of food unpredictability, housing and water-fasting on hematocrit levels in captive red crossbills, Loxia curvirostra

Hematocrit - or the percent volume of red blood cells in whole blood - is often referred to in papers as an indicator of body condition, yet it is responsive to a seeming myriad of factors, including factors that aren't necessarily related to body condition (e.g., elevation, metabolic demand and hydration). Some ambiguity may also arise from the fact that few studies directly investigate hematocrit but rather measure hematocrit because it is easy to do so and might prove interesting. We used an experimental approach to investigate the impacts of water availability, food availability and cage size (as an indirect manipulation of flight activity) on hematocrit levels in captive red crossbills (*Loxia curvirostra*). We found effects of food treatment and housing on changes in hematocrit and no difference following a short-term water restriction. We discuss these results in light of hypotheses about hematocrit and body condition.

98-2 CORNELIUS RUHS, E*; PIERSMA, T; CHASTEL, O; VÉZINA, F; Université du Quèbec à Rimouski, NIOZ Royal Netherlands Institute for Sea Research and University of Groningen, Centre National de la Recherche Scientifique; *ecornelius@wisc.edu*

Triidothyronine is associated with heat production but not energy intake in a long-distance migratory shorebird

Triiodothyronine (T3) is considered a regulatory hormone of thermoregulation in mammals and birds; however, its influence on maximal heat production (Summit metabolic rate, Msum) remains unknown. Thyroid hormones are also thought to be linked to food consumption. In cold environments both metabolic rate and food intake naturally increase to support thermoregulatory demands. It is therefore difficult to tease apart the role of T3 in heat production or energy turnover, separately. We studied indoor captive red knots (Calidris canutus islandica) maintained under two thermal treatments (cold and thermoneutrality) and at a natural photoperiod over a complete annual cycle. In the spring, the birds underwent a hyperphagic phase, which allowed us to tease apart the role of T3 in heat production and energy turnover. We predicted that if T3 is mainly involved in energy turnover, we would observe a peak in T3 during the hyperphagic phase for both thermal treatments and there would be no relationship between T3 and Msum. In contrast, if T3 is mainly involved in thermogenic capacity, then cold-acclimated birds would maintain higher T3 levels and T3 would correlate positively with Msum but we would not observe a peak for either treatment during hyperphagia. Our results did not show a peak in T3 during the hyperphagic phase for red knots held at cold or thermoneutral conditions. Further, Msum was positively correlated with T3 levels. These results are consistent with T3 playing a significant role in metabolic heat production. The correlation between energy turnover and thyroid hormones is likely resulting from cold environments requiring increases in both energy intake and heat production.

33-6 COST, IN*; ECHOLS, MS; MIDDLETON, KM; HOLLIDAY, CM; U of Missouri, Echols Veterinary Services; *incost@mail.missouri.edu*

Assessing the Biomechanical Environment of an Extinct Parrot (Psittaciformes) Using Extant Parrot Models

Cranial biomechanics are an understudied aspect of avian functional morphology despite numerous studies conducted on model organisms such as Darwin's Finches and birds of prey. One of the most biomechanically understudied but widespread groups of birds are the parrots (Aves: Psittaciformes). Globally distributed and representing numerous ecological niches, parrots represent a diverse array of feeding biomechanics despite similar cranial morphology. This similar morphology is optimized to dissipate stresses and mobilize the craniofacial hinge to increase the gape size available to parrots. We biomechanically tested finite element models (FEM) of 7 genera of parrots (*Strigops, Nestor, Melopsittacus, Psittacus, Deroptyus, Brotogeris*) and an outgroup species (*Falco*) that exhibit disparate diets including: folivory, omnivory, frugivory and granivory, and carnivory. Our FEMs were constructed with individual palatal elements linked by joint materials, biomechanically relevant constraints, and forces estimated using BoneLoad workflow for individual muscles. Posterior bilateral bite points were used to produce maximum bite force and approximate parrot feeding behavior. We used the FEM results as benchmarks to analyze the environment of the extinct parrot *Conuropsis carolinensis*, which had a known diet consisting of mostly seeds and fruits. As the only parrot native to North America, we hypothesized that *Conuropsis* would exhibit a stress profile similar to those of *Deroptyus* and *Brotogeris*; South American fruit and seed eating parrots. We found that *Conuropsis* is morphologically similar to other parrots and biomechanically similar to other granivorous parrots, regardless of phylogenetic proximity. Our innovative modelling methods show that extant and extinct biomechanical environments can be accurately recreated, described, and compared.

75-4 COSTA, DP*; KIENLE, SS; TRUMBLE, SJ; KANATOUS, S; GOEBEL, ME; KRAUSE, D; Univ. of California, Santa Cruz, Baylor University, Colorado State University, NOAA Southwest Fisheries Science Ctr; *costa@ucsc.edu*

Foraging Ecology of the Leopard Seal

The Antarctic Peninsula is one of the most rapidly changing habitats in the world. Although marine mammals have evolved diverse life history patterns and physiologies to accommodate extreme fluctuations in the physical and biological environment, their ability to cope with rapidly changing habitats in the Antarctic Peninsula is not well understood. To better understand the ability of the leopard seal, an apex predator in the Antarctic ecosystem, to cope with a changing environment, we examined the foraging behavior and habitat utilization of leopard seals using satellite telemetry. We successfully deployed 10 satellite-linked tracking devices on 3 adult male, 6 adult female, and one juvenile female leopard seal on Cape Shirreff Livingston Island, Antarctica during April-May 2018. Three of the ten leopard seals remained within the South Shetland Islands, while two female seals transited hundreds of kilometers to the northeast, and one paused at South Georgia Island. The telemetry tags also provided dive behavior currently being collected and analyzed. These diving and movement data are providing insight into the habitat requirements of this Antarctic top predator. Information on leopard seal dive behavior and habitat requirements are important ecological predictors in the face of climate change.

126-4 COUNTERMAN, BA*; FENNER, JL; Mississippi State University; *bcounterman@biology.msstate.edu*

Plasticity, hybridization and speciation on the Dogface butterfly wing

When two species successfully hybridize, there is potential for the hybrids to be isolated from the parental species, ecologically and/or reproductively, and to establish themselves as a new, hybrid species. Here, we re-visit a putative case of hybrid speciation among Dogface butterflies originally described in 1914 that has remained unexplored. The putative hybrids were described from a population in the San Bernardino mountains of Southern California, where the Southern Dogface (*Zerene cesonia*) and California Dogface (*Zerene eurydice*) have potential to come into contact. After successfully re-discovering the population with intermediate wing color patterns and the putative hybrid zone, we used a combination of comparative morphometrics of male genitalia and wing color patterns, population genomics, interspecific crosses and phenotypic plasticity experiments to test alternative hypotheses for the origin of the putative hybrid population with intermediate wing color patterns. Genomic and morphometrics showed little evidence of recent hybridization, yet laboratory crosses between the species yielded fertile F1. These findings suggest that although hybridization and gene flow may be possible, it occurs at a very low frequency for an extended period of time, and the intermediate population is not composed of recently generated intraspecific hybrids. Alternatively, by rearing butterflies in colder conditions we were able to generate intermediate wing patterns similar to those found in the putative hybrid zone. Collectively, our findings suggest that phenotypic plasticity, not hybridization, may be the major driver for the putative hybrids with intermediate wing color patterns.

P1-182 COURTS, LG*; KITTREDGE, MJ; PASK, GM; Bucknell University; *lgc009@bucknell.edu*

Cracking the CHC Code: Olfactory Communication in the Eusocial Harpegnathos saltator

Insects rely heavily on their sense of smell as a way to assess their surroundings and nearby organisms. In a lifestyle termed eusociality, bees, wasps, and ants form a hierarchy in which there are a limited amount of reproductive individuals and the rest become workers or nurses. Coordinated communication in the colony is mediated through the olfactory system, where each ant has a specific scent, acting as a "chemical ID", signifying one's own reproductive status, age, sex, etc. in the colony. These odors are made up of Cuticular Hydrocarbons (CHCs), which coat their exoskeleton. With the critical nature of smell for communication, there needs to be receptors to transmit and send the signal for higher level processing and recognition. *Harpegnathos saltator*, also known as the Indian Jumping Ant, has become a prime model for studying eusociality due to its reproductive behaviors, and the rapidly evolving 9-exon subfamily, which makes up the majority of CHC receptors. Focusing on specific HsOr lineages undergoing positive selection, we are examining how genetic variation can lead to differences in CHC sensitivity. Using an HsOr expression system in *Drosophila melanogaster*, we can functionally characterize odorant receptors within its genome. Utilizing electrophysiology, we can puff certain odors onto the fly that has a specific receptor, and see if there is a response based on their electrical signals that are being tracked. Through this work, we hope to understand how rapid evolution of olfactory receptors can facilitate the chemical communication required for the hierarchical lifestyle in ants and other eusocial insects. Building on this, by determining protein receptor structures, and identifying their function by accordance with smell, we may not only be able to preserve eusocial insect communities, but confront the issues of agricultural pests and human disease vectors.

95-8 COWART, JR*; ARNOLD, DM; STANTON, DL; VAN DER HORST, G; LARKIN, ILV; University of Florida, Gainesville, University of Florida, Lake Alfred, University of the Western Cape, South Africa; *jrc8462@ufl.edu*

A Comparative Structural Analysis of Spermatozoa From Three Evolutionarily-Related Species: the Manatee, Elephant, and Hyrax

Sperm characteristics, such as morphology and ultrastructure, constitute distinctive, evolutionary features of each individual species. Therefore, the spermatozoon is a useful element for studying the evolution of a particular species as well as the phylogenetic relationships between species. This study compared spermatozoal characteristics from three related species, the manatee, elephant, and hyrax, to further explore evolutionary and phylogenetic relationships. Morphology and morphometry were analyzed using a Sperm Class Analyzer computer-aided sperm analysis system (CASA) and ultrastructure was analyzed using scanning and transmission electron microscopy. Many ultrastructural similarities were found to exist between all three species. Each of the three species exhibited similar mitochondrial numbers, acrosomal coverage, and a unique similarity in the size of the outer dense fibers with an enlargement of 1, 2, 5 and 6. However, marked differences were apparent in the hyrax spermatozoon. The hyrax spermatozoon was notably different in both morphometry and overall shape and lacked a distinct diminishment along the equatorial acrosomal region, which was apparent in both the manatee and elephant. While many similarities exist, which highlights the unique phylogenetic relationship between these three species, the spermatozoon characteristics appear to be most similar amongst elephants and manatees suggesting a possible coevolution throughout time.

30-1 COX, RM*; COX, CL; WITTMAN, TN; MITCHEM, LB; CARD, DC; ANDREW, AL; CASTOE, T; MCGLOTHLIN, JW; University of Virginia, Georgia Southern University, Harvard University, Univ. of Texas, Arlington, Virginia Tech; *rmc3u@virginia.edu*

Hormonal regulation of gene expression and the developmental breakdown of between-sex genetic correlations in Anolis lizards

The evolution of sexual dimorphism is predicted to occur through reductions in between-sex genetic correlations for shared traits, but the mechanisms that facilitate this process remain largely speculative. We hypothesize that the sex-biased regulation of autosomal genes by sex steroids is a mechanism of general importance in the reduction of between-sex genetic correlations. Using a paternal half-sibling breeding design in captive brown anole lizards (*Anolis sagrei*), we show that the development of sexual dimorphism in body size is mirrored by the ontogenetic breakdown of between-sex genetic correlations for body size and growth rate. Using transcriptome data, we show that sex-biased gene expression also increases dramatically between ontogenetic stages bracketing this breakdown of genetic correlation, particularly for autosomal genes involved in growth, metabolism, and cell proliferation. Mechanistically, we show that treatment of females with testosterone stimulates the expression of male-biased genes while inhibiting the expression of female-biased genes, thereby inducing male-like phenotypes at both organismal and transcriptomic levels. Collectively, these results support the hypothesis that hormones with sex-specific patterns of circulation, such as testosterone, can facilitate the developmental breakdown of between-sex genetic correlations by orchestrating sex-specific gene expression. To to test this hypothesis directly, we present data from an experiment in which we manipulated testosterone levels in the context of a half-sibling breeding design to determine whether and how this sex-specific hormone structures patterns of within- and between-sex genetic correlation.

108-4 COX, CL*; CHUNG, AK; POLLOCK, NB; JOHN-ALDER, HB; ANDREW, AL; CARD, DC; CASTOE, TA; COX, RM; Georgia Southern University, GSU, University of Texas Arlington, Rutgers University, UTA, University of Virginia; *clcox@georgiasouthern.edu*

Evolution of hormonal regulation of sex-biased gene expression

Many endocrine networks are composed of autosomal genes that are shared between the sexes, which could theoretically impede the evolution of sexual dimorphism. However, hormones with sex-specific circulation (e.g., testosterone, or T) can be coupled and decoupled from the expression of shared regulatory networks to produce diversity in patterns of sexual dimorphism. We compared lizard species with male-biased sexual size dimorphism (SSD, two species) and female-biased SSD (one species) to test for the evolution of differences in how a sex-biased hormone (T) regulates sex-specific gene expression. Across the whole transcriptome, we found that while T stimulates the expression of male-biased genes, it inhibits the expression of female-biased genes for all three species. However, we found that those genes with male-biased expression in male-larger species tend to exhibit female-biased expression in the female-larger species. Similarly, we found that genes that tend to be stimulated by T in male-larger species tend to be inhibited by T in female-larger species. Finally, we found that these effects were observed specifically in growth regulatory gene networks, where T stimulated expression of growth-promoting genes such as IGF-1 in male-larger species, whereas these same genes were inhibited by T in female-larger species. Our research reveals how the relationship between a single pleiotropic hormone (T) and both the whole transcriptome and shared regulatory networks could facilitate the evolution of sexual dimorphism.

45-5 COX, S.M.*; RUBENSON, J.; Pennsylvania State University; *zanne@psu.edu*

Using OpenSim in Comparative Biomechanics: A Simple Approach

Opensim is a free open-source software package that was developed to enable users to ‘build, exchange, and analyze computer models of the musculoskeletal system and dynamics simulations of movement." Traditionally, most OpenSim models are very complex with 10-60 actuators and dozens of degrees of freedom. These models can take many years to develop and validate, making the approach less than ideal for comparative work where research often spans multiple taxa. But, OpenSim models do not need to be complex. Simple models can be built via Matlab scripts that would allow comparative biomechanists to harness the physics engine behind OpenSim to address broader biomechanical questions and take advantage of the thousands of brain-hours already invested in streamlining this process. In order to illustrate the method, strengths and limitations of using OpenSim, here I present three examples of models built to replicate or extend published comparative computational work. The first is a power amplified system consisting of a latch, motor, spring and a projectile intended to demonstrate how forward dynamic simulations of simple mechanical models can be constructed, modified and analyzed in OpenSim. Second, 2D frog model is presented to show how experimentally collected marker data can be used to scale a generic model to a species or individual's morphology and compute joint kinematics or, with force data, moments. Lastly, I present a 21 degree of freedom lower-limb model of a guinea fowl with 47 hill-type muscles to illustrate how OpenSim can be used to predict motor control patterns that would generate a prescribed motion. OpenSim is a powerful tool, in part, because of its community of sharing. Models and data are expected to be made freely available and are readily modified, allowing research to more easily build on the efforts of others.

P2-12 COYLE, J*; PORTER, ME; RODRIGUEZ, C; Florida Atlantic University High School, Florida Atlantic University, Pine Jog Environmental Education Center; *JASHCRA1@fau.edu*

Partnering with PreK-12 STEM education to propagate, track establishment and survivorship of native plants in Florida

The link between mycorrhizae, symbiotic fungi, and their host plants is well documented in many systems. Mycorrhizae provide direct physiological benefits to their hosts and also impact local soil conditions. In some families, such as orchids, the presence of mycorrhizae are critical even at the early stage of seed germination. In Florida, native orchid species are rapidly declining, largely due to habitat loss. The Florida Atlantic University (FAU) Pine Jog Environmental Education Center is using published micropropagation methods to grow and re-introduce native orchids into urban and natural areas across south Florida. As these orchids are re-established, mycorrhizal growth and morphotypes among species and planting conditions are monitored and studied. As a teaching tool, and to establish community activism, orchids are placed in local schools, including FAU's onsite lab school, A.D. Henderson, for students to propagate, study, and outplant. Students are active partners, cultivating plants and preparing them for distribution into urban and natural areas within their established native ranges. FAU High School students are learning microscopy techniques to quantify differences in mycorrhizal communities and overall plant conditions from orchids transplanted in natural compared to urban locations. These experiments engage students of all ages and expose them to hypothesis testing, experimental design, and propagation techniques. This project also encourages students to interact with the natural environment and consider the ecological consequences of urban development while re-establishing a declining native species.

140-4 CRANDELL, KE*; HOWE, RO; CANNON, C; FALKINGHAM, PL; Bangor University, Liverpool John Moores University; *k.crandell@bangor.ac.uk*

A comparative analysis of the hydrodynamics of beak shape kingfishers

Piscivorous birds have a unique suite of adaptations to forage under the water. One method of fishing for aerial birds is the plunge dive, wherein birds dive from a height to overcome drag and bouyancy in the water. The kingfishers are a well-known clade that contains both terrestrially foraging and plunge-diving species, allowing us to test for morphological and performance differences between foraging guilds. Diving species have narrower bills in the dorso-ventral and sagittal plane and longer bills (size corrected data, n=71 species, $p<0.001$ for all), Although these differences are confounded by phylogeny (phylogenetically corrected ANOVA for dorso-ventral $p=0.24$ and length $p=0.13$), beak width in the sagittal plane remains statistically different ($p<0.001$). We examined the effects of beak morphology on plunge performance by simulating dives with physical 3D printed models of kingfisher beaks coupled with an accelerometer, and through computational fluid dynamics (CFD). From simulated dives of bill models, diving species have lower peak decelerations, and thus, enter the water more quickly, than terrestrial and mixed-foraging species (ANOVA $p=0.002$), and this result remains unaffected by phylogeny (phylogenetically corrected ANOVA $p=0.04$). Preliminary CFD analyses confirm these trends in three representative species, and indicate that the morphology of the angle between the beak and head is a key site for avoiding additional drag in aquatic species.

9-1 CRANE, RL*; DENNY, MW; Stanford University, CA; *rlcrane@stanford.edu*

How bivalves fail: fatigue and fracture of California mussel shells

Bivalve shells provide protection from a variety of potentially lethal predatory and environmental threats. These threats range in frequency and magnitude from a single powerful predator strike to repeated insults from waves and tightly-packed neighbors. Shells' effectiveness at defending from such forces is traditionally quantified with a simple test of strength: a shell is rapidly compressed until it breaks. However, this technique cannot test the alternative possibility that low magnitude, repeated stresses can break a shell through the process of fatigue. We explored the threat of different realistic sources of shell damage by quantifying and contextualizing the strength and fatigue resistance of the California mussel (*Mytilus californianus*). We repeated the classic strength test by applying an increasing compressive force until fracture. Additionally, we used two distinct tests of fatigue resistance: a subcritical load was either applied constantly (i.e., static loading) or cyclically until fracture. Both fatigue tests considered a broad range of subcritical forces to mimic the forces experienced by mussels in the field. When stripped of living tissue, shells fatigued and broke under both static and cyclic loading conditions; lower forces required more cycles or longer static loading periods to result in shell fracture. This relationship demonstrates how the seemingly insignificant forces imposed by clamping shell valves or packing in a mussel bed could ultimately generate lethal damage, and invites the question of whether living tissue can somehow counteract the process of fatigue. These findings highlight how a range of accumulated threats might underlie variation in shell morphology and microstructure, and provide inspiration for future considerations of the evolution of shell form.

140-1 CRAWFORD, CH*; RANDALL, ZS; HART, PB; PAGE, LM; CHAKRABARTY, P; FLAMMANG, BE; New Jersey Institute of Technology, Florida Museum of Natural History, Louisiana State University, Louisiana State University; *chc24@njit.edu*

The Muscles That Move The Fishes That Walk

The rheophilic hillstream loaches (Balitoridae) of South and Southeast Asia possess a range of pelvic girdle morphologies which may be attributed to adaptations for locomotion against rapid flow. Specifically, the connectivity of the pelvic plate (basipterygium) to the vertebral column via a sacral rib, and the relative size and shape of the sacral rib, fall within a spectrum of three discrete morphotypes: long, narrow rib sometimes meeting with the pelvic plate; thicker, slightly-curved rib meeting or interlocking with the pelvic plate; and robust, crested rib interlocking with the pelvic plate. Species in the second and third categories with more robust sacral rib connections between the pelvic plate and vertebral column are capable of walking out of water with the third category exhibiting a more tetrapod-like lateral-sequence diagonal-couplets gait; this behavior has not been observed in balitorid species lacking direct skeletal connection between the vertebrae and the pelvis. Here, we present a myological analysis of the three morphotypes of balitorids to further address the functional morphology of walking in these fishes. Phosphotungstic acid (PTA) staining was used to increase the radiopacity of musculature for visualization with µCT scanning, after which individual muscle groups were segmented and analyzed for fiber angle and physiological cross-sectional area, to estimate maximum force production during locomotion. The skeletal and muscular morphological data from µCT scans were considered in a phylogenetic context based on robust sampling of ultraconserved elements (UCE). Future work will use kinematics and electromyography to compare the weight-bearing walking capabilities of balitorid species along the observed spectrum of pelvic girdle morphology.

70-6 CRISWELL, KE*; GILLIS, JA; University of Cambridge; *kc518@cam.ac.uk*

Evolution of Axial Segmentation Across Vertebrates

An axial column with segmented vertebrae is a key feature of the vertebrate body plan, but the diversity of developmental mechanisms that give rise to the axial column remains poorly understood. Vertebral elements derive from a series of mesodermal segments called somites. In tetrapods, somites are polarized, with adjacent somite halves recombining to form a single vertebra through a process known as "resegmentation". However, in teleost fishes, strict resegmentation is less apparent, with cells from multiple somites giving rise to a single vertebral half. To determine whether the process of resegmentation is ancestral for jawed vertebrates, we tested the relationship between somites and vertebrae in an outgroup to the bony fishes - a cartilaginous fish, the little skate (*Leucoraja erinacea*). We first demonstrate that skates and tetrapods share molecular markers of somite polarity. Next, using cell lineage tracing approaches, we show that the anterior and posterior halves of single skate trunk vertebrae derive from adjacent somites - a condition reminiscent of tetrapod resegmentation. Interestingly, the tails of cartilaginous fishes exhibit a condition known as diplospondyly, in which two vertebral units correspond with a single body segment. Lineage tracing of adjacent skate tail somites points to resegmentation in this region as well, though with each somite giving rise to half of one vertebra, an entire adjacent vertebra, and half of a third vertebra. These data demonstrate that the developing skate axial skeleton undergoes tetrapod-like resegmentation, that this process occurs across the entire axial skeleton (regardless of the mono- or diplospondylous conditions of the trunk and tail, respectively), and that resegmentation is likely an ancestral feature of the vertebrate axial skeleton.

P1-183 CROCKER-BUTA, S/P*; LEARY, C/J; University of Mississippi; *scrocker@go.olemiss.edu*

Hormonal and Social Correlates of Courtship Signal Quality and Behavior in Male Green Treefrogs

Circulating hormone levels vary among males competing for mates, but how this variation affects the signaling phenotype is poorly understood. In green treefrogs, *Hyla cinerea*, males competing for mates engage in vocal contests that increase corticosterone (CORT) and decrease androgens in contest losers, who adopt a non-calling "satellite" mating tactic. We previously showed that CORT administration to calling males reduces vocal effort and increases the probability of satellite behavior during simulated territorial intrusions, suggesting that elevated CORT compromises vocal quality and decreases the propensity to call in a context-dependent manner. However, the extent to which these effects reflect variation in vocal behavior of males in natural choruses is unclear. Here, we examined how hormone levels, social context, body size and condition relate to vocal attributes and behavior in calling males and in satellites after removal of calling "host" males. Results revealed that satellites had higher CORT, lower androgens, were smaller, and in poorer condition than hosts. Host removal resulted in vocalization in 74% of satellites. These males invested less effort in vocalization than hosts and CORT level best explained these differences. The remaining 26% of satellites did not vocalize after host removal and had lower androgens than satellites that vocalized. Results provide support for context-dependent effects (i.e., host presence/absence) of elevated CORT on the probability of vocalization and link high CORT to reduced vocal quality. In contrast, low androgens were associated with a low probability of vocalization regardless of social context and androgen level was a poor predictor of vocal attributes.

P1-180 CROCKER-BUTA, S/P*; HOLLOWAY, A; LEARY, C/J; University of Mississippi, Alcorn State University; *scrocker@go.olemiss.edu*

Female Green Treefrogs Prefer the Acoustic Courtship Signals of Unstressed Males

Variation in circulating levels of adrenal glucocorticoids can alter the expression of male sexual signals. However, whether variation in circulating glucocorticoid levels among courting males affects the probability of attracting females remains poorly understood. Here, we address this issue in the green treefrog, *Hyla cinerea*. Males of this species engage in aggressive vocal interactions that increase circulating levels of corticosterone (CORT) in rival male contest losers. We previously showed that CORT administration to calling males, simulating CORT production in vocal contest losers, decreases call duration and vocal effort, suggesting that elevated CORT compromises the attractiveness of male vocalizations. Using dual speaker playback experiments, we examined whether females show a preference for vocalizations characteristic of males with low versus high circulating CORT levels. Results from a total of 30 phonotaxis trials revealed that 24 females showed phonotaxis towards the speaker broadcasting calls characteristic of males with low CORT levels while only 6 females showed phonotaxis towards the calls characteristic of males with high CORT levels. These results indicate that females show a strong preference for the acoustic courtship signals of males with low CORT levels, suggesting that elevations in circulating glucocorticoids during male contests can diminish the probability of attracting females.

32-6 CROFTS, S. B.*; ANDERSON, P.S.L.; University of Illinois at Urbana-Champaign; *scrofts@illinois.edu*

The effect of cactus spine surface structure on puncture and anchoring performance

Although primarily thought of as defensive in nature, cactus spines have a wide range of other uses: shading, climbing, and dispersal to name a few. Similarly, there is a wide range surface ornamentation like barbs or tubercles. Despite this diversity, the mechanics of cactus spine function has yet to be fully characterized. Here we study the puncturing and withdrawing ability of six species of cactus, including both barbed and non-barbed spines. We found that barbed spines use less work to puncture biological and artificial targets than non-barbed spines. Barbed spines also require more work than non-barbed spines to withdraw from biological materials, due to their barbs engaging with tissue fibers. The variation in performance of barbed versus non-barbed spines, as well as between barbed spines from different species, is likely tied to the diversity of ecological functions for which cactus spines are used. In particular, the ability of barbed spines to anchor in to fibrous materials will aid dispersal of vegetative propagules. Finally, the relative performance of barbed cactus spines is similar to that of porcupine quills, implying some degree of biomechanical convergence across phyla.

P1-30 CROFTS, S. B. *; LAI, Y.; HU, Y.; ANDERSON, P.S.L.; University of Illinois at Urbana-Champaign, Georgia Institute of Technology ; *scrofts@illinois.edu*

Taking a stab at quantifying sharpness in snake fangs

The sharpness of biological puncturing tools plays an integral role in their function, as initiating fracture in a target material depends on the shape of the tool tip. There are various approaches to measuring tool sharpness, but how the different aspects of morphology affect puncture has yet to be studied. To understand what features of puncture tool tip affect the puncturing force, we turn to vipers as a case study. Viper strike is a quick, venomous bite and release that incapacitates prey and reduces their likelihood of injury. To understand the relationship between fang tip shape and fracture initiation, we took a two-pronged approach: 1) by measuring total fang length, tip sharpness index, tip surface area, and average included angle of fangs from 19 species and comparing these to the amount of force required to initiate fracture; and 2) creating and testing engineered puncture tools to separate the functional impact of included angle and radius of curvature on puncture initiation. When comparing the effect of fang tip morphology, only included angle showed a significant impact of force to initiate fracture, relative to the other morphological measurements. For the engineered punches, both included angle and radius of curvature have a significant effect on the force required to initiate fracture, with included angle having a greater impact. These data suggest that fang included angle is the strongest predictor of the force required to initiate fracture. Radius of curvature, which is used to determine sharpness index, is also an important predictor, though the influence of this factor becomes less significant at larger included angles.

P1-27 CROGHAN, J/A; Ohio University; *jasmine.croghan@gmail.com*

Two Turtles, Two Diets, Two Biomechanical strategies: Jaw Biomechanics in a Generalist Versus a Durophagous Species of Emydid

The diet of durophagous turtles impacts the shape and size of the skull, enabling the higher bite forces these species require to access hard-shelled prey. In a recent comparison, the durophagous *Malaclemys terrapin* was demonstrated to have a larger head relative to body size and therefore greater bite force than the closely related diet generalist, *Trachemys scripta*. Here, I test the hypothesis that jaw lever mechanics, not just relative head size, differ between the species, contributing to the higher bite force of *M. terrapin*. Female specimens of both species underwent diceCT, allowing me to digitally dissect the jaw closing musculature. The resultant 3D digital models were used to calculate lever mechanics of the jaws and measure the volumes of the jaw closing musculature. *M. terrapin* have 155% larger muscles relative to jaw length than *T. scripta*, which is indicative of a higher bite force capability even when scale for head size. Surprisingly, the line of action of the major jaw closing musculature differs between the species by less than one degree, indicating that neither is at an advantage for force input into the jaw lever system. The out-lever of the jaw was 4% larger in *M. terrapin* while the in-lever was 6% longer in *T. scripta*, suggesting that the mechanical advantage of the jaws is in fact higher in *T. scripta*. These results support that *T. scripta* possesses a mechanically more advantageous jaw system, but that the overall greater muscle volume relative to head size in *M. terrapin* is a major contributer to the observed differences in bite force between these species. Whether muscle architecture lends additional influence to the bite force capabilities of *M. terrapin* remains to be explored.

P2-212 CRONIN, AJ*; ROBERTSON, JC; ROBERTSON, John; Westminster College, PA; *robertjc@westminster.edu*
Structure of the Pyloric Cecum in Acipenseriformes
We are interested in comparative study of structure and function in North American Acipenseriform fishes. Here, we characterize structural features of the pyloric cecum in three species - paddlefish (*Polyodon spathula*), Atlantic sturgeon (*Acipenser oxyrhynchus*) and lake sturgeon (*Acipenser fulvescens*). In many fish species, the pyloric cecum is a prominent digestive organ thought to have absorptive and possibly secretory functions. Using preserved specimens of juvenile fish of about the same age and size, we determined morphometric indices that relate pyloric cecum dimensions to digestive tract and whole body measures. In addition, we use histology and image analysis to compare pyloric cecum cell and tissue features in the three species. Comparing the pyloric cecum in different species may offer insight into digestive adaptations associated with the different ways of life and diets of these diverse Acipenseriformes.

S12-9 CROSBY, AJ*; IRSCHICK, DJ; University of Massachusetts Amherst; *acrosby@umass.edu*
Adhesion Across Size Scales
Nature provides various examples, such as geckos, for how to sustain large forces across interfaces and, when desired, separate these same interfaces with minimal force. However, given the variety of structures and behaviors observed within geckos, a broad, inclusive framework for new understanding has remained elusive. To help provide insight into how evolution has enabled the scaling of reversible adhesion, and adapt to different external constraints, we have developed a general scaling theory that describes the force capacity of an adhesive interface in the context of biological locomotion. We have demonstrated that this scaling theory can be used to understand the relative performance of a wide range of organisms, including numerous gecko species and insects, as well as an extensive library of synthetic adhesive materials. We will present the development and testing of this scaling theory, and how this understanding provides new insight with regards to structure, form, and function. Overall, the developed scaling principles provide a framework for guiding comparative analyses in biology, as well as guiding the development of new adhesive-based technologies.

P2-248 CROWNOVER, L. A.*; ANDERSON, C. V.; University of South Dakota, Vermillion; *Lucas.Crownover@coyotes.usd.edu*
Exploring Axial Skeletal Function and Evolution in Chameleons using Micro-CT Technologies
Chameleons are well known for numerous highly characteristic anatomical and behavioral features such as their projectile tongue, prehensile tail, independently rotating eyes, and color changing abilities. With over 200 described taxa in twelve genera, however, chameleons are extremely diverse in their own right and come in a great variety of unique shapes and sizes. Among the most variable skeletal features in chameleons is the number of presacral (cervical, thoracic and lumbar) and caudal vertebrae, as well as the number of sternal and parasternal ribs. In fact, chameleons are known to have 14-23 presacral vertebrae, 17-62 caudal vertebrae, 3-4 sternal ribs, and 5-11 parasternal ribs. This variation, however, is based on the examination of a limited number of taxa and has not been put into a proper phylogenetic or ecological context (e.g., more arboreal vs. terrestrial species). We gathered and examined micro computed tomography (micro-CT) scans from 233 chameleon specimens, representing 155 different species of chameleon and five additional subspecies. This sample represents seventy-five percent of all described chameleon species, including all genera, and a previously unmatched body of data on the structure and function of this lizard family. From this examination, we quantified the rib and vertebral numbers across the family, including variation within genera. We then tested whether this variation correlates most closely with ecological characteristics or phylogenetic relationships within the family. These results provide insight into the evolution and function of the axial skeleton in chameleons and the morphological evolution of the axial skeleton across disparate ecological environments.

P3-132 CUEVAS-SANCHEZ, A Y*; MILLER, A; DOWD, W W; Washington State University; *a.cuevas-sanchez@wsu.edu*
Heat induced stressors in a changing environment: Thermal preference and activity assay of Tigriopus californicus
Splash-zone copepods *(Tigriopus californicus)* experience a variety of environmental fluctuations including changes in salinity, temperature, pH, and dissolved oxygen. We predicted that individuals acclimated to warmer temperatures would develop a thermal preference for cooler water, while also decreasing their activity level. Egg-mass-bearing females (n=48) were subjected to one of four temperature treatments for two weeks: 15°C, 19°C, 23°C and one treatment oscillating between 15-23°C each day. We assayed both activity patterns and thermal preference on each individual to examine the effects of fluctuating and constant temperature acclimation on behavior. We quantified activity of individual copepods in a novel, high-throughput microplate-based assay to look at the effects of acclimation to fluctuating and constant temperature on activity patterns during a controlled heat ramp (18-26°C). Results to date indicate that females acclimated to warmer temperatures have a thermal preference that averages ~4°C below their acclimation temperature, and those acclimated to a fluctuating thermal regime prefer temperatures close to the mean of the daily cycle. Meanwhile, copepods acclimated to 15°C preferred temperatures slightly above their acclimation temperature. Although there is only a weak effect of acute temperature change on activity levels during a heat ramp, there is evidence of decreased overall activity in copepods acclimated to higher temperatures. Our ultimate goal is to assess the ecological and evolutionary implications of environmental stress physiology and developmental plasticity of offspring in these dynamic and changing intertidal habitats.

P3-60 CUFF, AR; DALEY, MA; MICHEL, KB; ALLEN, VR; LAMAS, LP; ADAMI, C; MONTICELLI, P; PELLIGAND, L; HUTCHINSON, JR*; Royal Veterinary College; *jhutchinson@rvc.ac.uk*

Electromyographic Analysis Of Appendicular Muscle Function In Extant Archosaurs

Archosauria (birds, crocodiles and all descendants of their common ancestor) is characterized by remarkable locomotor variation across its evolution since the Triassic. More sprawling, quadrupedal crocodiles and more erect, bipedal birds are prime examples of this variation. The functional implications of musculoskeletal anatomy have been widely studied, but more experimental data are needed on how muscles control locomotor movements in extant archosaurs. We present new electromyographic measurements from key appendicular muscles across a range of walking and running speeds in Nile crocodiles and numerous species of birds (tinamous, emus, guinea fowl, pheasants, turkeys and quail). We consider how extant archosaurs control limb movements, and how neuromotor control has likely evolved. Crocodiles, like most other tetrapods, use their pectoral muscles in an antigravity role. Crocodiles' iliotibial, digital flexor and gastrocnemius muscles are activated similarly to birds (including Palaeognathae); likely ancestral for Archosauria. Birds, regardless of clade or ontogenetic status, show conservatism among the hindlimb muscles studied; these motor patterns appear ancestral for Aves. Our analysis is important for revealing which muscles display neuromotor conservation vs. evolutionary specialization. These findings are vital for testing the validity of computer simulations and reconstructing how locomotor disparity evolved in Archosauria.

P3-90 CULLEN, JA*; HALA, D; MARSHALL, CD; Texas A&M University, Texas A&M University at Galveston; *jcullen@tamu.edu*

Influence of Feeding Ecology on Accumulation of PAHs and PCBs in Three Sympatric Shark Species

Organic contaminants, such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), are ubiquitous within aquatic habitats and bind to organic material that can accumulate through food webs. Ecological tracers, such as stable isotopes $\delta^{13}C$ and $\delta^{15}N$, are useful to describe the resource use (foraging habitat and trophic position) of an organism within a given ecosystem. Although some previous studies have used stable isotopes to describe ecological sources of exposure to pollutants in fishes, this relationship remains unclear in sharks. Bull (*Carcharhinus leucas*), blacktip (*Carcharhinus limbatus*), and bonnethead (*Sphyrna tiburo*) sharks were selected for this analysis to compare sympatric species with different ecological niches from an industrialized basin (Galveston Bay, TX). Tissue-based burdens of 45 individual PAH and PCB congeners, as well as measures of $\delta^{13}C$ and $\delta^{15}N$, were quantified in muscle tissue of each species. We hypothesized that PAH and PCB burdens would vary among species as a result of differing isotopic niches and that $\delta^{15}N$ would be positively associated with increasing burdens of PCBs. A combination of univariate and multivariate analyses were conducted to discern the potential contributions of foraging habitat and relative trophic position to the accumulation of these pollutants. Patterns of pollutant burdens with isotopic niche were found within and among species.

56-3 CULLER, M.E.*; ONTHANK, K.L.; Walla Walla University; *monica.culler@wallawalla.edu*

Immune Function in Octopus rubescens in Response to Ocean Acidification and Warming

As the climate changes the ocean absorbs approximately 30% of the excess heat and carbon dioxide, resulting in a global ocean warming and acidification. These conditions strongly impact calcification and acid-base regulation in diverse marine invertebrates, but their effects on immune function have not been well studied. Some studies suggest these conditions may negatively affect immune function in bivalves and echinoderms, but similar studies on cephalopods are yet to be done. I measured the change in four immunological parameters in *Octopus rubescens* following three weeks in one of four treatments. Results indicate that future climate conditions may elicit slight changes in immune function, but that *O. rubescens* generally maintains regular immune function. This may suggest that this species prioritizes immune function when in suboptimal conditions.

P2-23 CUMMING, M*; SMITH, FW; University of North Florida; *n01403244@ospreys.unf.edu*

A Novel Developmental Mechanism Patterns Legs in Tardigrades

Panarthropoda is composed of three lineages of animals that possess legs—Arthropoda, Onychophora, and Tardigrada. Unlike onychophorans and tardigrades, arthropod legs are characterized by highly distinct morphologies along the proximodistal axis and joints. In both arthropods and onychophorans, the leg gap genes *Distal-less*, *dachshund*, *extradenticle*, and *homothorax* show regionalized expression patterns during leg development. *Distal-less* patterns the distal region of the leg, *dachshund* patterns the intermediate region of the leg, and *extradenticle* and *homothorax* work in combination to pattern the proximal region of the leg. These similarities reveal that a highly conserved developmental mechanism can underlie the evolution of very disparate leg morphologies. We investigated the leg gap genes in tardigrades to determine whether the mechanism identified in arthropods and onychophorans regulates development of the tiny legs of tardigrades. We identified single orthologs of *Distal-less* and *homothorax* in the genomes of two tardigrade species—*Hypsibius exemplaris* and *Ramazzotius varieornatus*. We identified three orthologs of *extradenticle* in these species. We could not identify a *dachshund* ortholog in these species, even though it is present in panarthropod out-groups, suggesting that this gene was lost in the tardigrade lineage. Using in-situ hybridization, we detected *Distal-less* signal in all developing tardigrade legs. Strong *homothorax* signal was restricted to the anteriormost leg pair. We detected weak signal in the second and third leg pair, and no signal in the fourth leg pair. Of the leg gap genes, only *Distal-less* appears to be required for development of all tardigrade legs. Therefore, our preliminary results suggest that, relative to the legs of arthropods and onychophorans, the tardigrade leg may only possess distal identity.

P2-66 CUNHA, FB*; WYLIE, D; GUTIERREZ-IBANEZ , C; IWANIUK, AN; Univ. of Lethbridge, Canada, Univ. of Alberta, Canada; *felipebrcunha@gmail.com*

How Do Neuronal Scaling Rules Apply to the Evolution of the Avian Cerebellum?

The rate at which the number of neurons increases with the overall size of the brain, and its constituent brain regions, varies across clades. This has led to the development of 'neuronal scaling rules', defined as the allometric relationship between neuron numbers and brain region volumes. Although these scaling rules appear to explain several aspects of brain diversification in vertebrates, it is unclear whether these scaling rules apply equally across different neuronal populations or to what extent neuron size follows brain region or clade specific scaling rules. To gain a better understanding of how neuronal scaling rules affect the evolution of species differences in brain region size, we quantified different aspects of the anatomy of the cerebellum, a key region for motor coordination that varies in size and morphology across species. Using unbiased stereology, we quantified the volumes of molecular, granule and white matter layers and the number and size of Purkinje cells across 60 species of birds. Phylogeny-based statistical analyses show that the different layers of the cerebellum evolve in a concerted fashion across all birds. In other words, when one layer increases in size, all the others increase at the same rate. Both the number and size of Purkinje cells, the sole output neurons of the cerebellar cortex, increase with cerebellum size, but Purkinje cells are added at a faster rate than they change in size. Last, more folded cerebella also had more and larger Purkinje cells. Thus, the evolution of larger cerebella is due to coordinated increases across cell layers as well as increases in the number and size of Purkinje cells according to a common set of neuronal scaling rules.

P1-156 CUPP, PV; 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. 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.

2-2 CURLIS, JD*; HOLMES, IA; DAVIS RABOSKY, AR; COX, CL; Univ. of Michigan, Georgia Southern Univ.; *curlisjd@umich.edu*

Evolutionary Linkage of Mimetic and Non-Mimetic Color Traits in a Coral Snake Mimicry Complex

Color polymorphism, in which multiple color patterns co-occur in a population, presents a paradox in mimicry systems with aposematism - if model resemblance is beneficial, then what is the adaptive significance of multiple morphs? Nevertheless, potential explanations for the maintenance of color polymorphism in mimicry systems include frequency-dependent selection, regulation via supergenes, sexual selection, and selection that varies over time and space. One way to test among these hypotheses is to compare mimetic and non-mimetic color traits, which may respond differently to selection. We tested how selection drives spatial patterns of these different types of color traits using the ground snake (*Sonora episcopa*), which is polymorphic for two mimetic traits (black bands, red stripe) and two non-mimetic traits (black cap, black collar). We analyzed spatial patterns of color traits using 1,240 individuals from 49 populations, conducted population genetic tests for selection using ddRAD sequence data, and modeled linkage relationships among color traits. We found mimetic and non-mimetic traits to be spatially and genetically linked with one another. We also found that both mimetic and non-mimetic traits are under diversifying selection, but the evidence for this selection is much stronger for mimetic traits than for non-mimetic traits. When taken together, our results imply that strong diversifying selection on mimetic traits may maintain polymorphism of both mimetic and non-mimetic color traits through genetic linkage, despite weaker selection on non-mimetic traits. Such findings present a previously-unstudied way in which phenotypic diversity can be maintained in mimicry complexes and have further implications for color pattern diversity across the tree of life.

109-1 CURREA, JP*; THEOBALD, JC; Florida International University; *jcurr001@fiu.edu*

Regionally Specific Temporal Summation Improves Motion Vision in Small Fruit Flies

For holometabelous insects, low larval feeding results in small but otherwise normal adults. In fruit flies, this results in conspecifics with small eyes that sacrifice contrast sensitivity optically but recover that sensitivity by sacrificing temporal acuity neurally. However, forward optic flow generates peripheral motion that offers crucial information about flight speed and orientation. Normally, this difference is resolved optically: many fast moving insects have greater inter-ommatidial angles and larger ommatidial apertures in lateral regions of the eye. But fruit flies have a nearly homogeneous eye structure and the temporal summation used by small flies in their central vision would cause substantial motion blur in the periphery. Do small flies process motion differently between central and peripheral visual regions? To address this, we used a flight simulation arena and measured contrast sensitivity and spatial and temporal acuity by displaying moving sinusoidal gratings and measuring their turning behavior with a wingbeat analyzer. Then, using a microscope, we measured the flies' eye size, ommatidial count, and average ommatidial area. As before, we found that smaller eyes temporally summate when motion is in their central vision. But when motion was displayed in their periphery, small and large flies responded nearly equally. In fact, aside from a small difference in peripheral spatial acuity likely due to differences in acceptance angle, small flies demonstrated little loss in peripheral visual ability. Alternatively, it seems large flies can afford a central region of high temporal acuity not found in smaller flies.

95-4 CURRY, JE*; NAVARA, KJ; University of Georgia; *jcurry@uga.edu*

Effects of safflower and flax seed oil on primary sex ratio in Japanese quail, Coturnix japonica

Sex ratio manipulation is a well-documented phenomenon in numerous avian species. Females, the heterogametic sex in birds, are able to alter their sex ratios in response to a variety of factors in order to maximize their reproductive success. Two prevailing influences on sex ratios are food availability and maternal condition (measured by fat content), and in a study conducted in Kakapo parrot, a diet high in fat skewed sex ratios towards males. We hypothesize that a diet's fat content may be a key factor involved in skewing sex ratio. In the present study, we aimed to test the influences of high dietary fat on offspring sex ratios in Japanese quail. We chose safflower oil and flax seed oil as our main fat components based on the dietary composition that skewed sex ratios in Kakapo parrots. Sexually mature Japanese quail were pair-housed in a climate and light controlled environment with free access to feed and water. Half were fed a traditional quail diet crumble and the other half were given a diet formulated with 5% safflower oil and 5% flax seed oil balanced accordingly. The quail were given an adjustment period of two weeks before we collected eggs for an additional two weeks. The collected eggs were incubated for 3 days, frozen, and then embryonic tissue was dissected and molecularly sexed. The sex ratio of pairs given the high fat diet was found to be male-biased and significantly greater ($F = 6.66$, $p = 0.01$) than those of the control, and this effect appeared to occur independently of body weight. These data suggest that fat quantity and fat quality of a bird's diet may be a trigger of sex ratio adjustment in birds.

P1-97 CURRY, JE*; NAVARA, KJ; University of Georgia; *jcurry@uga.edu*

Natural sex ratio bias in Japanese quail, Coturnix japonica

Many studies in various avian species have reported sex ratios deviating from the expected 1:1 male to female ratio. This literature almost exclusively focuses on various factors that can influence sex ratio, such as food availability or mate attractiveness, while few studies examine sex ratios in the absence of these environmental and social cues. One such study in Eclectus parrots found that females in captivity produce long strings of only one sex before switching to the other. This extreme bias was observed in multiple females from multiple breeders. We hypothesize that this phenomenon of skewed sex ratios with no outside influences may occur in other birds. We tested this by observing three flocks of Japanese quail and monitoring sex ratios for two weeks under identical environmental and dietary conditions. The quail were pair housed in temperature and light controlled facilities and given free access to food and water. Eggs were collected, incubated, and sexed via dissection or molecular techniques. In our study, we refer to sex ratios below 0.4 as female biased and those above 0.6 as male biased. In flock one, we found 25 fertile pairs (those that produced at least seven fertile eggs in the two-week span). Of those, five were female biases while eight were male biased. In flock two we found 27 fertile pairs, of which six were female biased and seven were male biased. We tested to see if these biases could be explained by female body condition and found that sex ratios were independent of body mass. Data from third flock is still being analyzed, and these sex ratios will be compared to male and female body morphometrics. Given the multiple examples of bias in two separate flocks, we believe that Japanese quail may alter their sex ratios independent of currently known cues.

P1-153 CURTIS, KM*; MOORE, PA; MARTIN III, AL; Saginaw Valley State University, Bowling Green State University; *almarti2@svsu.edu*

The Effects of Population Structure on Crayfish Aggression

Animals participate in agonistic interactions to secure or maintain necessary resources. Crayfish fight vigorously when introduced, with aggressive behaviors decreasing in frequency and duration as the population stabilizes. This results in dominant and subordinate relationships between individuals; interactions between different sized crayfish cause the large animal to become dominant, while the small animal becomes subordinate. However, populations of crayfish are complex and are difficult to assess. Mutual- and self-assessment are ways animals evaluate conspecifics within a population. Theoretical models by Mesterton-Gibbons and Heap (2013) proposed that assessment and aggression within populations differ in relation to varying resource value. This study attempts to empirically address one piece of this puzzle, the influence of population structure on aggression. Populations of crayfish (4 large, 4 small, 3 small vs. 1 large, 2 small vs. 2 large, 1 small vs. 3 large) are provided with 4 identical shelters and are recorded for 24-hour trials for fight duration and outcome. Preliminary fight duration data suggests populations with primarily large animals (4 large, 3 large vs. 1 small) fight longer as compared to populations with equal or a greater number of small animals (2 large vs. 2 small, 1 large vs. 3 small). Additionally, numbers of fights are found to be greater in populations with all large animals. This data suggests populations consisting of larger crayfish increases the overall aggression of the population. This study, along with future studies involving differing resources, will provide empirical evidence to better understand how resources and assessment strategies collectively influence the intricacies of population structure.

56-8 CYPHER, A.D.*; HERSHBERGER, P; SCHOLZ, N; INCARDONA, J.P.; NOAA Northwest Fisheries Science Center, USGS Western Fisheries Research Center, NOAA NWFSC, NOAA NWFSC; *alysha.cypher@noaa.gov*

Larval cardiotoxicity and juvenile performance are likely contributors to the delayed fishery collapse of Pacific herring after the Exxon Valdez oil spill

Several years after the 1989 Exxon Valdez oil spill, the Pacific herring (*Clupea pallasi*) population of Prince William Sound crashed and never recovered. Despite finding that larvae are sensitive to very low concentrations of polycyclic aromatic hydrocarbons (PAHs), the connection between oil spills and delayed mortality at the population level has yet to be established. The developing heart is the primary target of crude oil toxicity and a strong hypothetical starting point for a cascade of events leading to reduced recruitment at the population level. To establish this, we evaluated larval cardiac morphology and growth through metamorphosis in addition to juvenile cardiorespiratory performance. Herring embryos were exposed to 0 to 5.1 ppb $\sum$PAHs from 24 hours post fertilization to 10 days and subsequently reared in clean sea water. Concentrations were maintained by a dispersion generator which injected microdroplets of Alaskan North Slope crude oil into the exposure system. Cardiac morphology was assessed weekly by video microscopy through metamorphosis, approximately 80 days post hatch. At near-detection limit concentrations, we observed cardiac edema and altered ventricular shape. This was accompanied by reduced cardiorespiratory performance in juveniles. Ongoing studies relate cardiorespiratory performance, growth, and infectious disease resistance which are strong determinants of population-dynamics. Therefore, larval cardiotoxicity and reduced juvenile performance at least partially explain the delayed mortality observed after the Exxon Valdez oil spill. This work is part of a larger collaboration to evaluate the relationship between larvae and juvenile physiology and population decline.

47-6 DABE, E.C.*; MCCRACKEN, A.R.; MOROZ, L.L.;
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Nervous System Evolution and Neuronal cell-type Innovations in Euthyneura Molluscs

Euthyneura gastropod molluscs have undergone several independent events of nervous system centralization, such as the gain/loss of the abdominal ganglia or visceral ganglion. Yet this clade also has homologous single neurons that have been conserved across million of years of evolution-the longest traced neuron homology of any system- making Euthyneura ideal for studying the genetic basis of nervous system evolution with cellular resolution. We compared transcriptomic profiles of sensory systems, CNS, ganglia, and single neurons from *Pleurobranchaea californica* to the genome of neuroscience model *Aplysia californica* and to transcriptomes of eight other related Euthyneura species. 9% of genes expressed in the eyes of three Aplysiidae species were potential orthologs to genes expressed in *P.californica* and *Tritonia diomedea* eyes-which are non-functional - and with *Octopus bimaculoides* eye transcriptomes. This analysis of Euthyneura eyes helps to further establish potential ancestral origins of molluscan eye diversity. For the first time, we assessed the homology of the abdominal/visceral ganglia in Euthyneura and found only 13% of genes showed conserved expression. The repeatedly identifiable abdominal cholinergic (ACh) motor neuron R2, that controls mucus release, has 500 conserved orthologs across 3 species of Aplysiidae. Although ACh biosyntheis genes have similar gene expression patterns in the abdominal ganglia across these species, the *Bursatella leachii* homologous R2 neuron does not express any ACh biosynthesis genes, suggesting a potential reorganization of abdominal ganglia structure and function.

40-1 DAKIN, R.*; RYDER, T. B.; Smithsonian Institution;
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Dynamic Network Partnerships and Social Contagion Drive Cooperation

Both reciprocity and positive assortment (like with like) are predicted to promote the evolution of cooperation, yet how partners influence each other's behavior within dynamic networks is not well understood. One way to test this question is to partition phenotypic variation into differences among individuals in the expression of cooperative behavior (the "direct effect"), and plasticity within individuals in response to the social environment (the "indirect effect"). A positive correlation between these two sources of variation, such that more cooperative individuals elicit others to cooperate, is predicted to facilitate social contagion and selection on cooperative behavior. Testing this hypothesis is challenging, however, because it requires repeated measures of behavior across a dynamic social landscape. Here, we use an automated data-logging system to quantify the behavior of 179 wire-tailed manakins, birds that form cooperative male-male coalitions, and we use multiple-membership models to test the hypothesis that dynamic network partnerships shape within-individual variation in cooperative behavior. Our results show strong positive correlations between a bird's own sociality and his estimated effect on his partners, consistent with the hypothesis that cooperation begets cooperation. These findings support the hypothesis that social contagion can facilitate selection for cooperative behavior within social networks.

P1-170 DAKIN, R*; HORTON, B. M.; VERNASCO, B. J.;
MOORE, I. T.; RYDER, T. B.; Smithsonian Institution, Millersville University, Virginia Tech, Virginia Tech; *roslyn.dakin@gmail.com*
Understanding the androgen basis of individual differences in cooperation

Social behavior is a near-ubiquitous characteristic of vertebrates, and interaction dynamics are often driven by repeatable differences in behavior. Although variation in vertebrate social behavior has a well-known endocrine basis, most of the work on hormone-behavior relationships has focused on archetypal behaviors (e.g., aggression) in relatively simple social systems. As a result, we know little about how hormones modulate complex behaviors, like cooperation, that rely on repeated interactions within a dynamic social landscape. Here, we examined how testosterone (T) modulates social behavior in a lekking species, the wire-tailed manakin (Pipra filicauda), where territorial and non-territorial "floater" males form cooperative display coalitions. Our approach combined repeated hormone sampling, hormone manipulations and a novel automated telemetry system to measure social behavior. First, we asked if T could explain repeatable variation in male-male cooperation (i.e., the number of display partners and the frequency of interactions). Our results reveal that among-individual differences in circulating T predict behavior, but that these relationships are status-specific. Higher T correlates with increased cooperation among floater males but is inversely related to cooperative tendencies among territorial males. Additionally, T manipulations confirm that experimentally-elevated T can inhibit cooperation by territorial individuals with the strongest effects seen in males with lower endogenous T levels. We propose that these status-specific effects are due to differences in the neural activity of androgens and our results highlight how status specific differences in circulating T can influence cooperative behavior.

114-5 DALY-ENGEL, TS*; LYTLE, DA; WHEELER, DE; SMITH, RL; Florida Institute of Technology, Melbourne, Oregon State University, Corvallis, University of Arizona, Tucson, University of Arizona, Tucson; *tdalyengel@fit.edu*
Sexual Selection on Competitive Females Drives the Evolution of Male Parental Care in the Giant Water Bug, Abedus herberti (Hemiptera: Belostomatidae)

Exclusive male parental care, a form of sex role-reversal, may evolve when males invest more heavily in reproduction than females. Here, competition for mates should intensify sexual selection among females, while males must mitigate fitness loss from polyandry. Yet true sex role-reversal, which involves increased selection on competitive females, is rare in nature, even in species with male parental care. In giant water bugs *Abedus herberti* Hidalgo (Hemiptera: Belostomatidae), females glue their eggs to males' backs to be tended until hatching, while males attempt to ensure paternity by inseminating females between ovipositions. We investigated the genetic mating system of *A. herberti* in southern Arizona to determine whether paternal care evolved in the context of selection on polyandrous females. Using microsatellite DNA, we conducted parentage assignment and measured rates of polygynandry, ecological correlates, and strength of sexual selection in 1,341 individuals (123 adults and 36 broods). Results showed that both polyandry and genetic cuckoldry are common, with an average 36% of brooding males carrying offspring sired by another male, an effect that is enhanced by ecological density. Strength of sexual selection was significantly higher on females than males, where paternal care and reciprocal cuckoldry ensured less benefit from remating. We conclude that selection on polyandrous females has helped to drive the evolution of paternity assurance and male parental care in the giant water bug *Abedus herberti*.

P1-149 DAN, M*; GIRALDO, YM; DICKINSON , MH; California Institute of Technology, Pasadena; *mdan@caltech.edu*

Seasonality in Drosophila Sun Navigation

The fruit fly, *Drosophila melanogaster*, flies across vast distances by means of a navigation system which is visually guided by celestial cues. As a non-diapausing insect, we wanted to shed light on how *Drosophila* might arrive at seasonally inhospitable habitats, such as the Mojave Desert, by testing whether seasonal temperature and light conditions affect *Drosophila* flight headings. We reared wildtype *Drosophila melanogaster* under divergent daylength and temperature conditions to simulate summer, winter and spring. After reaching adulthood, flies were tethered and placed in a flight simulator, which surrounds the fly with a visual panorama in which we displayed a simulated sun (bright spot) or a landing site (dark, vertical stripe). A machine-vision software tracked the fly's wing strokes, allowing the fly to control the azimuthal angular velocity of the stimulus. An analysis of flight headings suggests that flies reared under winter conditions tend to fixate the sun frontally, thus performing phototaxis, whereas summer and spring flies adopt a wider range of non-frontal headings, ie. menotaxis. Seasonal variations in flight heading were observed within a single generation, which led us to investigate whether other physical characteristics — wet mass and pigmentation — vary plastically. We found significant variation in wet mass between the seasonal treatments, with winter females weighing less and males weighing more than their spring and summer counterparts. Comparing the reflectance percentage of abdomen and thorax pigmentation, we found significantly darker regions on the winter flies. In conclusion, our data lends support to the hypothesis that seasonal developmental conditions can affect navigation strategy and physiology.

88-7 DANIEL, TL*; KOEHL, MAR; Univ. of Washington, Seattle, Univ. of California, Berkeley; *danielt@uw.edu*

Foul Play: How Epibionts Affect the Hydrodynamics of Macroalgae

Macroalgae provide habitat for myriad epiphytes. Hydrodynamic forces can break or dislodge algae and epibionts, both of which depend on flowing water for nutrient transport. How do the mechanical interactions between algae and their epibionts affect their performance in ambient water flow? To address this question, we used the blade-like red alga, *Mazzaella splendens*, and the encrusting byrozoan, *Membranipora membranacea*, to investigate the biomechanical and hydrodynamic consequences for algae bearing epiphytes and for the epiphytes of living on flexible algae. We found that algal blades with encrusting bryozoan colonies had a higher flexural stiffness than blades without colonies. While flexible, unfouled algae reconfigured in ambient flow into more streamlined shapes, stiffer encrusted algae did not, and thus experienced higher hydrodynamic forces. Blade tissues had lower elastic moduli and broke at higher extension ratios than did bryozoan colonies, so when a blade was stretched, ebibiotic colonies fractured and popped off the blade. Algae in habitats exposed to rapid flows had few epibionts, whereas those in slow-flow habitats were heavily fouled. Fouled algae transplanted from a protected habitat to one exposed to rapid flow lost their epibionts. We measured mass transport rates at algal surfaces in the field and showed that fouled and unfouled algae experienced greater transport rates near their attached ends than at their distal ends. Field dye studies showed that algal flapping increased the rate at which water near the substratum was replaced by new water. Bryozoan cover was greatest on the older, high-transport basal regions of blades. Thus, flapping by algae enhances transport to the algae and their epibionts, while the epibionts increase the drag on the host, but the extensibility of algal tissue leads to removal of epibionts in rapid-flow habitats.

S5-3 DANTZER, B*; WESTRICK, SE; MONAGHAN, P; HAUSSMANN, M; BOUTIN, S; HUMPHRIES, MM; LANE, JE; MCADAM, AG; VAN KESTEREN, F; University of Michigan, University of Glasgow, Bucknell University, University of Alberta, McGill University, University of Saskatchewan, University of Guelph; *dantzer@umich.edu*

Maternal glucocorticoids alter a network of offspring traits in red squirrels but are these changes adaptive?

Maternal hormonal responses to environmental or social cues have well-known effects on many offspring characteristics. This includes offspring traits that directly interface with the environment (behavior, life history traits) to those that may underlie variation in such traits (endocrine axes, antioxidant levels, telomere lengths, etc.). The changes in offspring traits caused by maternal hormonal responses may be coordinated and produce an adaptive shift in a network of offspring traits. However, the effects of variation in maternal hormone levels on offspring are often investigated in a univariate fashion. We have been examining if changes in maternal glucocorticoids (GCs) in North American red squirrels (*Tamiasciurus hudsonicus*) in the Yukon, Canada impact offspring stress reactivity, insulin-signaling, oxidative stress state (oxidative damage, antioxidants, telomere lengths) in addition to their life history traits, behavior, and fitness. We will describe the results from our field studies where we treated breeding females with exogenous GCs and documented their effects on a range of offspring traits. We will discuss these results in the context of our other field studies documenting whether the coordinated changes in offspring traits that we observed are adaptive for specific environmental conditions. By integrating these different studies together, our results highlight the benefits of using a multi-level perspective to examine how changes in maternal hormones affect offspring.

BART-1 DANTZER, B; University of Michigan; *dantzer@umich.edu*

Plasticity, hormones, behavior, and fitness: understanding the long-reach of the mother in wild animals

In 1930, the animal ecologist Charles Elton wrote about the "*scattered state of ecology*" using a macabre analogy. To Elton, ecology was "*like an active worm that has been chopped into little bits, each admirably brisk, but leading a rather exclusive and lonely existence*". Bartholomew agreed with Elton given his own views about the importance of integration across biological disciplines and the need to build connections among the different levels of biological investigation rather than erect walls between them. Unlike Elton, to Bartholomew, the touchstone or integrating tendency of biological investigations should be the whole organism. By placing the whole organism and its natural history at the center of any study, Bartholomew thought that one could perform integrative studies where lower (mechanisms) and higher (function) levels of biological investigation complemented one another. I have tried to heed the warning of Elton and the advice of Bartholomew by examining integrative research questions spurred by an appreciation of natural history. Like Bartholomew, I am fascinated with understanding the ecological and evolutionary causes and consequences of variation in the physiology, behavior, and life histories of wild animals. I will discuss some of my research about how ecological conditions that induce changes in maternal glucocorticoids can cause shifts in the growth, physiology, behavior, and life histories of wild red squirrels and meerkats. Some of this plasticity in offspring traits is adaptive, supporting predictions from evolutionary theory that adaptive phenotypic plasticity can facilitate organismal resilience in capricious environments. Finally, I will illustrate how different outcomes from the similar experiments that I have conducted in two species support another viewpoint from Bartholomew that it may be "*foolish to look for general answers to specific questions*".

P2-131 DANZIGER, A*; FREDERICH, M; University of New England, Biddeford, ME; *adanziger1@une.edu*

Using eDNA and FlowCam Analyses for Green Crab Monitoring

The invasive Green crab, *Carcinus maenas*, and Asian shore crab, *Hemigrapsus sanguinaeus*, have rapidly increased their populations, particularly on the coast of Maine, leading to a significant and detrimental effect on coastal intertidal areas. We have monitored both populations in Biddeford Pool over 6 years. Our data show that both species are established in the area and have reproductive seasons that overlap, but peak about 4 weeks apart during early summer. In addition, green crabs were shown to be egg bearing in the winter months. To determine if their eggs are viable year-round, and produce viable larvae, we designed a remote-controlled boat with an attached plankton suction device that can be deployed in shallow and deep waters. The plankton suction device is comprised of a 60 cm 4 inch acrylic pipe with a BlueRobotics T100 thruster, 200 µm plankton net, and a General Oceanics mechanical flowmeter. Samples collected with the RC boat-driven plankton sucker were analyzed using a FlowCam particle imaging system. Due to a lack of crab larvae abundance in the FlowCam-analyzed samples, we designed an environmental DNA (eDNA) protocol to detect the presence of green crabs in the water column. Focusing on the COI1 gene of green crabs and other crustaceans in Maine, such as the Asian shore crab, the Jonah crab, *Cancer irroratus*, the rock crab, *Cancer borealis*, and the American lobster, *Homarus americanus*, we designed specific quantitative PCR primers and probes for green crabs. We then set up a filtration system to separate isolate eDNA from the plankton tows using the Qiagen DNeasy kit. We are correlating FlowCam and eDNA analyses to test which method allows for a reliable and economically viable monitoring program for marine invasive species. Supported by NSF grants MRI-1624984 and IUSE-1431955 to M.F.

44-3 DARCY, HE*; ANDERSON, PSJ; University of Illinois Urbana-Champaign; *hdarcy2@illinois.edu*

Quantifying Phenotypic Variation in a Tooth-Bearing Bone in Spelerpinae Salamanders

The vomer is an important tooth-bearing cranial bone in the lungless salamanders (Plethodontidae) that displays different morphologies according to the feeding environment of the adult. Aquatic-feeding salamanders present vomerine tooth rows parallel with the maxillary teeth that are thought to help grasp prey while expelling water from the mouth. Terrestrial-feeding adults retain the parallel row from the larval state but extend the tooth row posteriorly, forming an L-shape, so that the teeth may help bring prey down the throat. However, the overall morphology of the vomer itself appears to vary taxonomically rather than by habitat. To study these two influences on vomerine shape, we examined species of the morphologically diverse subfamily Spelerpinae, in which two of the five genera (*Eurycea* and *Gyrinophilus*) present both aquatic and terrestrial species. 3D data were collected using micro computed tomography (microCT) scans from specimens from the Field Museum of Natural History and the Illinois Natural History Survey, representing four of the five Spelerpinae genera. Geometric morphometric (GM) analyses were performed to capture shape variation of both the vomer and the vomerine tooth row, using a combination of landmarks and semi-landmarks. Results show multiple influences on vomer shape variation in both aquatic and terrestrial taxa, with taxonomic position showing larger influence in terrestrial taxa.

18-4 DAVID, KT*; OAKS, JR; HALANYCH, KM; Auburn University; *kzd0038@auburn.edu*

Much Ado About Orthologs: Consequences of Duplication and Speciation in Gene Evolution

In eukaryotic lineages, genes typically replicate through either speciation or gene duplication events. After a speciation event, resulting gene copies (orthologs) are generally expected to maintain similar evolutionary rates, as function is typically conserved. After a duplication event, however, resulting gene copies (paralogs) may differ in evolutionary rates and a broader set of possible fates may be realized, including partial (subfunctionalization) or complete loss of function (nonfunctionalization), as well as gain of new function (neofunctionalization) in at least one of the descendant copies. Many popular gene annotation databases indirectly assume conservation of substitution rates between orthologs and divergence of rates between paralogs. Unfortunately, studies which explicitly compare evolutionary processes between speciation and duplication events are rare and conflicting. To provide an empirical framework of ortholog/paralog evolution, we estimated the rate ratio of nonsynonymous to synonymous substitutions (dN/dS) of 213,808 branches in 8,470 gene trees across 77 vertebrate taxa. Overall, we found lineages descended from speciation events had significantly ($p<0.001$) more similar dN/dS ratios to one another than did lineages descended from duplication events. However, there are several branches near the base of the vertebrate tree where we either do not recover significant differences between change in dN/dS between orthologous and paralogous branches or find significant support for the opposite hypothesis: more similar dN/dS ratios between paralogous branches than orthologous branches. We discuss possible interpretations of this surprising result and conclude that orthologous relationships are often, but not always, associated with more conserved evolutionary rates than paralogous relationships.

76-4 DAVIDSON, L.A.; University of Pittsburgh; *lad43@pitt.edu*

Mechanical Design in the Embryo: M.A.R.K.-Style Dissection of Functional Mechanical Contributions from Laminar Sheet to Molecular Complex.

To connect genes to processes that drive morphogenesis requires analysis of the impact of specific genes on the varied structures that contribute to mechanical properties of the embryo. Gastrulation and axis elongation in vertebrate embryos involves remodeling a sphere or disk of cells into a long body plan that resembles that of the adult. By contrast with later morphogenetic movements that shape complex 3D structures, axis extension proceeds as a relatively simple rearrangement of cells in a 2D plane. Using the elongating dorsal tissues of the Xenopus embryo, our group has developed a complete set of experimental tools and theory for direct biomechanical analysis to study tissue self-assembly. In this presentation I apply a M.A.R.K.-style biomechanical analysis to investigate structural origins of changing tissue mechanical properties through manipulations on the large-scale laminar structure of the embryo, control of cell size, and cell cortical cytoskeleton. Embryonic tissues increase stiffness nearly 10-fold over the course of gastrulation. Surprisingly, we find little contribution from emerging large scale structures in the embryo, such as the central column-like notochord or lateral beam-like pre-somitic mesoderm. However, the major contributor to changing tissue mechanical properties appears to lie in the cytoskeletal composition, but not thickness of the cell cortex. Expression of mutant and full length forms of the F-actin cross-linker protein α-actinin (ACTN1) alter tissue mechanics to the same magnitude as observed during development. Further analyses of modulators of the actomyosin cell cortex will uncover how gene regulatory networks establish and control embryonic as well as somatic tissue mechanical properties.

55-2 DAVIES, SW*; CASTILLO, KD; BOVE, CB; RIES, JB; Boston University, UNC Chapel Hill, Northeastern University; *daviessw@bu.edu*

Local Adaptation and Transcriptome Plasticity of a Resilient Caribbean Coral

Local adaptation is ubiquitous in marine environments, however populations are increasingly exposed to environmental perturbations under climate change, which could constrain the benefits of being locally adapted. Instead, in rapidly changing environments, it might be beneficial to be plastic to counter environmental change. To understand potential tradeoffs between adaptation and plasticity in corals, we conducted a four year, three way reciprocal transplant experiment of the resilient Caribbean coral *Siderastrea siderea* across forereef (FR), backreef (BR), and nearshore (NS) environments in Belize. Calcification rates varied by natal reef environment and by transplant location, with corals originating from and living in FR locations calcifying the fastest, suggesting that FR environments are more suitable for growth. Evidence of local adaptation was only observed for FR corals, which exhibited the highest growth rates in their native reef environment. Notably, all corals exhibited high survival in the FR and BR, but corals transplanted to the NS experienced high mortality, suggesting that NS environments present strong environmental selection. Transcriptome profiling 3.5 years post transplantation revealed that both transplanted coral hosts and their algal symbionts exhibited transcriptome profiles more similar to other colonies residing on the same reef, regardless of source location suggesting that transcriptomic plasticity facilitates acclimation to environmental change in *S. siderea*. Our results suggest that there is the capacity for local adaptation in *S. siderea*, however, this adaptive competence is limited by strong environmental selection and facilitated by transcriptomic plasticity. Collectively, these findings help explain the recent success of this species on reefs across the greater Caribbean.

106-7 DAVIS, HR*; BAUER, AM; JACKMAN, TR; Villanova University; *hdavis5@villanova.edu*

When Being Generic Makes You Diverse: Phylogenetic and Morphological Diversity of the Gecko Genus Cyrtodactylus .

The genus *Cyrtodactylus* is a hyper-diverse group of lizards ranging from South Asia to Melanesia, with a dense concentration in the Sundaland region. The lizards are successful in both degraded and primary rainforests and they excel in habitats that offer opportunities for climbing. Their scansorial lifestyle and ability to partition substrates and microhabitats allows up to three congeners to be found living sympatrically in a given area. Four primary environmental associations have been recorded throughout their range: leaf/twig, tree trunk, swamp, and rock. By focusing on the species in eastern Malaysia on the island of Borneo, we sought to determine whether geographically disjunct species inhabiting similar niches were converging on a specific morphology. To understand if the species sharing a given niche are closely related, we generated species trees using one mitochondrial and three nuclear loci. We found that habitat preference does not correlate with species relatedness, indicating that multiple independent invasions of specific niches have occurred. With the polyphyletic relationships amongst substrate specialists, we looked for morphological characteristics shared between representatives from each of the four ecotypes to determine if convergent evolution is occurring. Using the morphological characters, we conducted a principal component analysis which shows only weak clustering for substrate association. With a lack of support for the monophyly of ecotypes and little evidence for convergence, we suggest that the success of the genus stems from a combination of having a strong ability to climb while retaining a relatively large, generalist body.

P2-220 DAVIS, JS*; GANNON, JL; High Point University; *jdavis0@highpoint.edu*

Is There Osteological Evidence of a Prominent Zygomaticomandibularis in Hypocarnivorous Mammals?

Several studies have shown a relationship between fusion of the mandibular symphysis and late unilateral activity of the balancing-side zygomaticomandibularis muscle, thought to facilitate the production of transversely-oriented grinding movements during mastication, particularly among species that specialize on plant-based diets. The recurrence of this pattern across mammalia is compelling evidence of convergent adaptation in the masticatory apparatus. Given the importance of the zygomaticomandibularis in this pattern, we hypothesize that this muscle may differ not only in the timing of its activity, but also in its morphology and prevalence among the jaw adductors in species with a fused mandibular symphysis and plant-based diet, when compared to related species with omnivorous or animalivorous diets and patent symphyses. To investigate this relationship, three parallel 3D geometric morphometric analyses are used to characterize the shape of the mandibular ramus in three separate mammalian lineages that include species that are representative of the ecomorphological groups of interest: musteloid carnivorans, xenarthrans, and phyllostomid bats. We focus on the mandibular ramus because its shape is influenced by attachment sites for the major jaw adductors, including the zygomaticomandibularis, and we investigate whether there are convergent trends in its shape among species with plant-based diets.

P1-218 DAVIS-BERG, EC*; ROCK, MO; RAMIREZ, I; ALMARIO-KOPP, D; WILSON, BA; Columbia College Chicago, Chicago IL, University of Illinois at Chicago and Garfield Park Conservatory, Liberty Public Schools; *edavisberg@colum.edu*

Fitch Natural History Reservation, a study in molluscan succession in a re-established forest ecosystem

The Fitch Natural History Reservation was founded in 1948 and is located in Douglas County, Kansas. Prior to the foundation of the reserve, the non-forested areas were heavily cultivated or grazed. Since the late 1940s, the reserve has been allowed to undergo natural succession, returning to a primarily forested ecosystem. In some areas of the reserve, succession has caused a rapid increase in foliage, resulting in a dense underbrush. Molluscan surveys were conducted in the late 1940s through the 1950s, which often included a species list, specific locality information within the reserve, and information on the vegetation growth at the time. We have periodic molluscan collections at three terrestrial sites and one aquatic site from 2004 through 2017. By comparing the more recent collections with the older data, we demonstrate how the molluscan fauna has responded to succession on this reservation over the last 50 years. We have found almost all species documented in the original surveys while conducting our own surveys. We have found an increase in the forest species found at the Reservation as well as a decrease in the grassland species, providing evidence that the molluscan fauna change with the vegetation.

54-8 DAWSON, KR*; RICHARDSON, DC; WEATHERS, KC; Winston Salem State University, Suny New Paltz, Cary Institute of Ecosystem Studies; *kdawson115@rams.wssu.edu*

How ecosystem function differs across a gradient of lake sizes: Don't forget about the little ones

Freshwater ecosystems are important for species conservation efforts and also for providing insight on a variety of ecosystem functions. Until recently, lakes and rivers have been the main focus for research on freshwater systems, leaving small lakes and ponds virtually overlooked and understudied. Reports have suggested that ponds may be more important than previously thought. This study aims to observe how ecosystem measures, such as ecology, biology, and physics, differ across a gradient of lake sizes. We observed thermal stratification, zooplankton density, DOC (dissolved organic carbon), chlorophyll-a and conductivity between lakes in the Shawangunk Ridge. We studied the following sites: Awosting Lake, Lake Minnewaska, Mohonk Lake and Mud Pond. To observe the thermal stratification of the lakes, temperature sensors were mounted on a chain that reached the deepest part of both largest and smallest lakes (Awosting Lake and Mud Pond). They recorded the temperature every 15 minutes for roughly a month. For the ecological component, we collected water and analyzed samples from both deep and shallow sites in each lake. Our results indicated that DOC, and chlorophyll-a were all higher in the Mud Pond. Whereas, zooplankton density and conductivity where highest in Mohonk Lake. We also observed that Mud pond was much less stratified and experienced more water mixing than Awosting. Our data suggest that in various ways, Mud Pond can differ drastically from larger lakes. Learning from these small water bodies may prove to be vital in our overall understanding of freshwater ecosystems. Ponds and small lakes need to be protected and studied because they have the potential to help us better understand the influences of global climate change, food webs, and even greenhouse gas emissions.

P3-85 DAWSON, KR*; LIGHTSEY, J; DOUGLAS, K; DZIKUNU, G; SOUSA, J; SHORT, Z; ALLEN, L; DZIKUNU, Georgi; Winston Salem State University; *kdawson115@rams.wssu.edu*

Assessing Ecological Water Quality Along a Creek: Preliminary Data

Streams and rivers are some of the most biodiverse freshwater ecosystems, and yet they face many threats. They are often subjected to various forms of pollution, habitat degradation and resource exploitation. This study aims to use macroinvertebrates as an indicator of ecological water quality at various sites along a single creek (Salem Creek) in Winston Salem, North Carolina. We predicted that as the stream approached the urban area, we would observe a reduction in macroinvertebrate diversity and abundance. We collected samples at 5 locations along the creek spanning the entire 9+ miles of the creek's length and used sampling locations that were approximately 2 miles apart. We used two sampling methods at each site. We used a kick net and a standard aquatic net to sample macroinvertebrates. Following field collection, we separated the macroinvertebrates from any debris, preserved them in 70% ethanol and later identified them to order/sub-order. If we observe that the diversity of the macroinvertebrates decreased the farther downstream, it would indicate that pollutants may be entering the water at multiple points thus lowering the quality of the water. We have also collected water samples to share with collaborators in Chemistry and Biology to measure chemical compounds and bacterial strains present at these sites. We plan on utilizing these same sampling methods to test the quality of additional waterways throughout Winston Salem. After we analyzed the types and number of species collected at each site, we concluded that 4 out of the 5 sites were fair in quality. However, one site was not, and we plan to further investigate the reason why.

120-6 DE BRUIJN, R*; GILMOUR, KM; HINCH, SG; PATTERSON, DA; COOKE, SJ; Carleton University, Canada, Univ. of Ottawa, Canada, Univ. of British Columbia, Canada, Fisheries and Oceans Canada; *debruijn@chapman.edu*

Bile: an alternative matrix to assess stress status in migrating and spawning salmonids?

There is increasing interest in understanding how anthropogenic and natural disturbances affect the ability of fish to thrive and reproduce. To assess effects of such disturbances on fish, glucocorticoids (GC) are commonly measured as a way to assess the stress status of the animals. While plasma samples are the gold standard, plasma GC concentrations are relatively volatile and can change rapidly in response to a disturbance, such as the sampling itself. The hepato-biliary-fecal route is the main clearance route for GC in fish and bile may thus be an interesting alternative matrix to assess GC status. Furthermore, it is thought that bile GC concentrations are less sensitive to acute disturbances, thus potentially providing a more integrative measure of the stress status of an individual. Bile may especially be interesting in fish where fecal sampling may not be possible, either because the fish don't form solid enough casts, or because the fish may not be producing enough fecal matter, e.g., in salmonids that fast for the duration of the spawning season. The main goal of this project is to assess the viability of bile as a matrix to assess the stress status of individual Pacific salmon during migration and spawning. We aim to develop a reliable and relatively straightforward protocol for obtaining and analyzing bile samples from migrating and spawning salmonids. For this project, bile samples were collected from different stock of Pacific salmon at different stages of migration along the Fraser river system in British Columbia, Canada. More specifically, we aim to validate the need for extraction and purification, as well as the suitability of commercially available ELISA kits for analysis of these samples.

77-2 DEBIASSE, MB*; BABONIS, LS; KOREN, S; SCHNITZLER, CE; MARTINDALE, MQ; RYAN, JF; Whitney Lab for Marine Bioscience, National Human Genome Research Institute; *melissa.debiasse@gmail.com*

The complete genome sequence of Beroe ovata, a tentacle-less, ctenophore-chomping ctenophore

Ctenophores occupy an important place in the animal tree of life with respect to phylogeny and ecology, and characterizing ctenophore genome structure improves our understanding of animal diversity. Here we present the genome of the lobate ctenophore *Beroe ovata*. Given the divergent feeding ecology and morphology of *Beroe* compared to the species whose genomes were sequenced previously (*Mnemiopsis leidyi* and *Pleurobrachia bachei*), the *B. ovata* genome fills an important gap in our knowledge of ctenophore diversity. We assembled the *B. ovata* genome from Pacific Bioscience sequencing reads using Canu and a novel post-processing method that retains unique genes while reducing the number of erroneously incorporated haplotigs. Our *B. ovata* genome assembly is ~156 MB with an N50 of 187,314 and 16, 548 predicted genes. Assessments of assembly completeness were high with 91% and 96% of complete and complete+partial BUSCO core genes represented, respectively. We identified four *Wnt* pathway genes (*WntA*, *WntX*, *Wnt6*, *Wnt9*) in *B. ovata* that are expressed in tentacle bulbs in *M. leidyi*. This result is surprising given that *B. ovata* lacks tentacles and the regeneration ability associated with stem cells in tentacle bulbs. *Beroe ovata* has three opsin genes, but two lack the conserved lysine required for chromophore binding, meaning only one opsin is functional. The *B. ovata* genome has 48 photoprotein genes clustered on 8 different genomic scaffolds, 5x more than found in *M. leidyi*, suggesting a large-scale duplication in *B. ovata* photoprotein genes; these findings suggest the clustering of photoprotein genes in both *M. leidyi* and *B. ovota* is important for functional bioluminescence in ctenophores.

P2-22 DEBIASSE, M; COLGAN, W; RODRIGUES, D*; RYAN, J; DAVIDSON, B; Whitney Labs, UFL, Swarthmore College; *drodrig2@swarthmore.edu*

Developmental systems drift in tunicate heart gene regulatory networks

Developmental systems drift (DSD) is a form of evolution where a trait or developmental process remains conserved despite changes in the underlying gene regulatory network. Regulatory elements in developmental gene networks often undergo substantial drift, including changes in the order, number or position of transcription factor binding sites. Examining the drift or conservation of regulatory elements across large periods of evolutionary divergence can provide insights into the structure and function of these elements in a network. We compared the heart gene regulatory networks of two tunicate species Ciona robusta and Corella inflata to explore how a long period of DSD, ~ 250my, has altered a functionally conserved gene network. One of the primary nodes in this network is Mesp, an initial cranial-cardiac transcription factor in both tunicates and vertebrates. Here we show that the Mesp enhancer is regulated by conserved upstream transcription factors in both species despite significant changes in sequence. Through serial minimization of a Corella Mesp reporter construct, we found that the location of the enhancer had shifted considerably in comparison to the characterized Ciona enhancer. Cross-species testing of the Ciona and Corella enhancers indicated that conserved upstream transcription factors regulate mesp expression in both species. Mutation of predicted binding sites for these conserved transcription factors revealed that functional important sites had shifted in their spacing within the enhancer while number and order appeared more constrained. These studies indicate that specific structural features of initial regulatory elements in vital development networks are highly constrained, perhaps due to rigorous temporal or spatial expression requirements.

P1-215 DEBIASSE, MB; BUCKENMEYER, A*; BABONIS, LS; BENTLAGE, B; COLLINS, AG; DALY, M; MACRANDER, J; REITZEL, AM; STAMPAR, SN; RYAN, JF; Whitney Lab for Marine Bioscience, University of Guam, National Museum of Natural History, Smithsonian Institution, The Ohio State University, Florida Southern College, University of North Carolina at Charlotte, Universidade Estadual Paulista; *melissa.debiasse@gmail.com*

Placing leaves on the cnidarian tree of life

Cnidarians are a stunning group of animals with diverse ecologies, life histories, and morphologies. Relationships within the cnidarian tree of life have been the subject of controversy for many years and the position of several nodes, especially within the Anthozoa, remain unresolved. This project aims to clarify the relationships among and within cnidarian lineages by combining transcriptome data from 32 newly sequenced taxa in Actinaria, Ceriantharia, and Octocorallia with previously published sequence data from 63 additional taxa. We use an innovative approach that combines a backbone phylogeny estimated from hundreds of loci across 95 taxa with a single-locus 18s phylogeny comprising over 900 taxa. To produce our phylogenomic data set, we assembled RNA sequence data into taxon-specific transcriptomes in Trinity, identified orthogroups across taxa in OrthoFinder, and used a novel pruning approach to remove paraphyletic and monophyletic duplicates from orthogroups. Our resulting data matrix contains 101 genes with 15,286 aligned amino acid sites for 89 cnidarian and 6 outgroup taxa with 78% occupancy. To generate the 18s data set, we mined Genbank for all previously published cnidarian 18s sequences. We use the backbone phylogenomic tree to infer deep nodes and to constrain the 18s sequences, producing the most comprehensive cnidarian phylogeny to date. Deployed together, these data sets will enable the resolution of deep and shallow phylogenetic relationships among cnidarian taxa. These resolved relationships can serve as the foundation for trait-based analyses, and will improve our understanding the evolutionary history of cnidarian innovations.

P2-150 DECONINCK, AD*; NIELSEN, ME; HILL, CA; EMANN, W; KINGSOLVER, JG; University of North Carolina--Chapel Hill, Princeton Day School; *aimeed@live.unc.edu*

None Like It Hot: Larvae Move to Avoid Hot but Not Cold Temperatures, Regardless of Rearing Temperatures

Terrestrial ectotherms commonly use both physiological and behavioral strategies to avoid extreme temperatures and to maintain body temperatures within a thermal range that improves growth, development and survival. Developmental temperatures can alter maximum growth rate and optimal body temperatures, and ectotherms may use thermoregulatory behavior to maintain preferred temperatures for their relative optimum. Do developmental temperatures also affect thermoregulatory behaviors? We address this question using the Tobacco Hornworm, *Manduca sexta* . We reared larvae after hatching in either constant or diurnally fluctuating thermal conditions and tested at the 4th (of 5th) larval instar. To determine their preferred temperatures, larvae were placed on a gradient plate and subjected to either increasing or decreasing temperatures for one hour. Initial results suggest that while larvae from both rearing treatments respond behaviorally to escape high temperatures, they do not respond to low temperatures. We are continuing investigations to understand the contribution rearing history may have in modifying these behaviors.

P2-116 DEES, LH*; HOFFMAN, AJ; WADA, H; Auburn High School, Auburn University; *lesliedees1@gmail.com*

Alteration of eggshell characteristics due to maternal heat stress

In birds, the last step of egg formation is deposition of eggshell which provides a physical barrier for embryos. A match among eggshell characteristics, embryonic demand for gas exchange through pores, loss of water through pores, and environmental condition are critical in proper embryonic development as the metabolic rate of embryos and the demand for greater gas exchange both increase when embryos develop under high temperatures. Recent studies have shown that eggshell characteristics are under natural selection in birds which recently colonized new environments with different temperature and humidity compared to ones in the source population. However, maternal control of eggshell characteristics in response to environmental changes is largely unknown. We hypothesized that eggs whose mothers were exposed to heat while young would have greater pore densities and lower thicknesses to allow for greater gas transfer with the outside air. Towards the end, the goals of this study were to investigate whether thermal environment of mothers as juveniles and/or right before egg laying determined the eggshell thickness and pore density of the eggs they lay. Captive zebra finch females were divided into 4 groups in a fully factorial design where females experienced control (22C) or mild heat (38C) for 28 days during the juvenile period and control (22C) or high heat (42C) for 3 consecutive days as an adult. We found that only the pore density was subject to the thermal environment of the mother, with mothers exposed to heat treatment both as juveniles and adults producing eggs with the greatest pore density, and surviving offspring exhibiting greater pore densities. These results suggest that mothers have the ability to adjust eggshell characteristics so eggs are better adapted to the predicted thermal environment.

138-1 DEETJEN, M. E.*; CHIN, D. D.; TOBALSKE, B. W.; LENTINK, D.; Stanford University, University of Montana; *mdeetjen@stanford.edu*

Muscles, 3D Wing Shape, and Aerodynamic Forces in Bird Flight

Whereas the majority of terrestrial and aquatic locomotion involves complex muscle interactions such that no one muscle dominates, the power needed for bird flight is primarily provided by only two muscles: the pectoralis and the supracoracoideus. The pectoralis in particular, produces the majority of the aerodynamic lift needed for flight, and is the dominant muscle during the downstroke. The dominant nature of this single muscle, makes the downstroke a simpler model system for studying the function of muscles in general than most other modes of locomotion. In order to quantify pectoralis muscle function during flight for doves, we combine multiple measurement techniques synced in high speed. First, we measure the performance of the pectoralis using sonomicrometry to measure muscle strain, and electromyography (EMG) to measure muscle activation. Second, with an external array of cameras and projectors, we use structured-light to reconstruct the morphing 3D shape of the bird wings. Lastly, the flight arena itself is an aerodynamic force platform which measures the vertical and horizontal aerodynamic forces produced by birds flying from perch to perch. Together, these measurements enable us to trace how internal pectoralis muscle forces translate into aerodynamic forces during downstroke, and help us to better understand muscle function in bird flight and animals in general.

19-3 DEFINO, N.J.*; FOX, J.L.; Case Western Reserve University, Case Western Reserve University ; *noah.j.defino@gmail.com*

Dissecting the effects of flight behavior and neuromodulation on gaze control

Animals integrate multiple senses in order to understand the body's relation to its surroundings. Flies use visual and proprioceptive clues to detect body rotations during flight using their eyes and halteres (modified hind wings). With input from both of these sensors, flies can stabilize their gaze to minimize motion blur during body rotations. Stabilizing head movements are only observed during flight, suggesting that neuromodulation (for example, by the transmitter octopamine, which is upregulated in flight) may mediate this behavior. Here, we use genetic manipulations of *Drosophila* to determine octopamine's role in modulating gaze. In tethered insects, octopamine is not necessary for spontaneous head movement. When flies are presented with widefield visual stimuli in the yaw axis, however, octopamine is necessary for producing a gaze stabilizing optomotor response where head movements are coordinated with the visual stimulus. Conversely, when tethered flies are rotated about the yaw axis, with or without visual stimuli, octopamine is not necessary for coordinated head movements during flight, but is necessary for coordinated head movement when not flying. During flight, the halteres oscillate and detect yaw rotation. Our results suggest that when flies are not flying and their halteres are still, they use other sensory organs to detect rotation, and these sensory organs are modulated by octopamine. Increasing octopamine concentrations did not restore optomotor responses, indicating that octopamine is not sufficient for initiating gaze stabilizing optomotor responses, and that active flight is needed as well. Additionally, these findings indicate that octopamine does not have a direct effect on the motor control of neck movement, but fosters head-visual coordination through its modulation of visual neurons.

P1-84 DEGON, ZD*; NICHOLSON, DJ; CHUNG, A; TAYLOR, Q; CURLIS, JD; LOGAN, M; NEEL, L; DUBOIS, MM; MCMILLAN, WO; COX, CL; Georgia Southern University, Queen Mary University of London, Smithsonian Tropical Research Institute, Arizona Univesity, Northeastern University; *zd00214@georgiasouthern.edu*

Sex-specific relationships between energetics and ecotoparasites in a tropical lizard

Tradeoffs among energy allocation to growth, reproduction, and immune function can impact fitness. While both sexes allocate energy to reproduction and immune function, tradeoffs between these functions may be structured in a sex-specific fashion. Specifically, the energetic costs of immunity can differ temporally between the sexes due to behavioral and energetic differences, but this sex-biased energy allocation is not understood for most species. We studied the relationships between ectoparasite (mite) load, organ mass, fat body mass, and total body size in the Panamanian slender anole. We hypothesized that the quantity of mites should increase with the body size and that both sexes would allocate energy away from immune function towards energetic investment in reproductive tissues. We found that larger lizards did have more mites in both sexes. However, only males with greater fat body mass had higher ectoparasite loads. In contrast, the number of mites increases with the size of the ovaries, but not with the size of the testes. We suggest that the number of mites reflected the amount of endogenous fat storage in males, which implies that abundant energetic stores can be channeled in to the immune response to suppress mite infection. In contrast, females that had greater energy invested in reproductive tissues had correspondingly greater mite infections, which implies that investment into reproduction trades off with investment into immune function. Our results suggest that ectoparasites affect energy allocation in ways that are likely to generate sex-specific patterns of fitness in wild ectotherms.

52-1 DELANEY, DM*; JANZEN, FJ; Iowa State Univ., Iowa State University; *dmdelane@iastate.edu*

Risk-sensitive Maternal Investment: Evaluating Parent-offspring Conflict Over Nest-site Choice

Parents increase their fitness by investing resources to offspring. However, such investment is often costly for parents, leading to tradeoffs. Furthermore, such tradeoffs should shift towards heavier investment to reproduction as females age and future reproductive opportunities decrease. Nests of aquatic turtles laid farther from water have higher survival than those laid closer to shore because nest predators often forage along environmental edges. However, the predation risk for adult females increases farther from water because water is used as refuge from terrestrial predators. Thus, females may balance investment in current offspring vs. maternal survival and future offspring. To test if investment varies depending upon perceived risk, we exposed 30 painted turtles (*Chrysemys picta*) to simulated predation during natural nesting attempts. We then allowed females to return and nest undisturbed, and compared the distance to water of nests laid before and after simulated predation. Unexpectedly, females did not vary distance to water in response to simulated predation. Regardless, nests laid after simulated predation were more likely to be depredated than those laid before simulated predation, suggesting females altered nest-site choice in ways we did not quantify. In addition, although older turtles nested almost twice as far from water as younger turtles, we found no evidence that age influenced maternal response to simulated predation. Our findings suggest perceived risk for mothers to predation influences nest-site choice and subsequently reduces offspring survival in C. picta. In addition, we provide a rare assessment of how plastic maternal investment might vary across reproductive life.

P1-240 DELGADO, AL*; DALY, MA; Portland State University, The Ohio State Univeristy; *delgado7@pdx.edu*

Using DDRAD to infer population distribution of Pederson Cleaner shrimp in the Caribbean Oceans

In this study, we investigated the phylogeographical distribution of a subset of the Caribbean lineage of the Pederson cleaner shrimp, Ancylomenes pedersoni. We focused on the southern range of the Caribbean lineage, which is represented within three sites: Mexico, Honduras, and Panama. The area in which these sites are found was thought to represent one homogenous A. pedersoni population with no genetic structure (Debiases 2015). We employed DDRAD sequencing to obtain a clear resolution of the species distribution. Ipyrad was used to clean data and produce output files. SVDquartets and Maximum Likelihood analysis were used to assess phylogeny and population structure. Adegenet was used to test for a number of populations and relatedness at different levels of structure. Analyses revealed that the three tested sites are indeed panmictic (k=1), but that genetic structuring may be present within two of the sites. This study also shows that gene flow is mostly one-directional—from south to north—and reveals signs of bottlenecking. Further analysis will look at the Caribbean wide lineage of the Pederson Cleaner Shrimp.

P1-52 DELGADO GOMEZ, S*; BATTAGLIOLI, S; HOWELL, M; CIERI, RL; FARMER, CG; University of Utah, University of Utah; Trinity College Dublin; *samurldelgato@gmail.com*

Microfluidics and Gas Exchange in Reptilian Parenchyma

Almost nothing is known about the flow of gases very close to and within the gas exchange parenchyma of any reptile, yet this flow is a crucial determinant of gas-exchange capacity. The parenchyma is diverse, ranging from simple trabecule, where branching structures form a polygonal network along the lung wall, to faveoli, with a honeycomb appearance. Our recent work on gross patterns of airflow within the lungs of a variety of reptiles suggests that much of the flow is unidirectional and laminar, which could increase the thickness of boundary layers and impede gas exchange. To better understand the relative contribution of diffusion and advection to gas exchange at the microscale level, we have: (1) developed physical models of the lung walls; (2) simulated gas exchange. The physical models were created using micro-CT of a green iguana to generate a surface file, which was scaled to maintain dynamic similarity when water flowed over the surface at steady state (Re ≈ 8-12), and 3D printed with PLA filament, or laser cured resin. Polyamid seeding particles (50 µm ø) were visualized using Flocoach™ model B1. The gas-exchange simulations were generated for a series of 2D wells, with geometries typical of reptilian respiratory parenchyma, using Fluent and Peclet # <<1. Our results indicate the faveoli are an impediment to convection and suggest thick boundary layers impede gas-exchange with flow at steady state. We found little evidence of vortices developing within the faveoli. These results point to the importance of cardiac pulsations of the vasculature or smooth muscle for improving mass transport. Funded by NSF IOS CAREER-1055080, NSF 1256065, NSF ACI-1238993, and Enterprise Ireland.

P1-114 DESANA, AN*; FARGEVIEILLE, AK; WARNER, DA; Seton Hill University, Greensburg, PA 15601, Auburn University, Auburn, AL 36849; *a.desana3@setonhill.edu*

Lizard Egg Predation by Marsh Crabs: Effects of Microhabitat and Crab Density on Egg Survival

Predation is a key factor in population regulation and evolutionary processes. For oviparous species with no parental care, vulnerability to predation is critical at the egg stage and female nest site choice can reduce egg predation. Based on observations of square-back marsh crabs (*Armases cinereum*) eating brown anole eggs (*Anolis sagrei*), we designed indoor and field experiments to answer three questions: 1) are marsh crabs a major predator of brown anole eggs, 2) does egg predation differ among microhabitat types, and 3) how does crab density affect egg survival? In both experiments, we placed incubating eggs in three different natural and relevant microhabitats: open area, palm frond, and leaf litter. We also manipulated the placement of the eggs as either buried or placed on the surface. Both experiments confirmed square-back marsh crabs as anole egg predators. We also found a difference in egg survival depending on microhabitat type; placement of the egg was crucial for egg survival in the open area microhabitat. Crab density did not affect egg survival in our field experiment. These results suggest that selection of nest site by female brown anoles can affect their offspring survival in the presence of marsh crabs.

64-4 DESCOUR, M E*; DEVRIES, L D; EVANGELISTA, D E; United States Naval Academy; *m191368@usna.edu*

Soft robotic designs inspired by leeches

Soft robotic designs have the potential to provide improved maneuverability and durability compared to hard-bodied robots. We present on-going work to examine soft robotic designs inspired by leeches (Hirudinea: Lamarck, 1818). The segmented body plan of annelids is appealing for engineering designs in which pressure can be used as a means of controlling movement. We will discuss locomotion and attachment as observed in live leeches, then we will present new leech-inspired designs. By constructing a soft bodied robot with segmented soft pneumatic actuators and controlling them according to biologically inspired gaits, we hope to accomplish various modes of locomotion that could be useful within a bulk fluid, along a surface, within a thin film, or along an interface. The soft pneumatic actutors must control bending along the body, so we will discuss the relationship between input pressure, curvature, bend angle, and speed within a body segment. We will also discuss methods for attachment/detachment at the anterior and posterior ends of the robot. The locomotion and attachment designs will ultimately be combined in a soft robot capable of leech-like locomotion, which could be useful in search and rescue in challenging environments, in soft designs for medical devices, or in locomotion systems designed to traverse multiple environments in the presence of free surfaces or boundaries. Biomechanics and engineering are a two-way street; constructing bio-inspired soft bodied robots may provide further quantitative insight into the form and function of the organisms that served as the original inspiration.

P1-137 DESIMONE, JG*; GUTIERREZ RAMIREZ, M; BREUNER, CW; ELOWE, CR; GRIEGO, MS; GERSON, AR; University of Montana, University of Massachusetts Amherst; *joely.desimone@umontana.edu*

Baseline corticosterone and body composition of Gray Catbirds at stopover during spring migration

Each spring, neo-tropical migratory birds traverse the Gulf of Mexico en route to their breeding grounds, often stopping to refuel along the northern Gulf coast. Baseline levels of the metabolic hormone corticosterone (CORT) have been hypothesized to be elevated during migratory flight, reduced during refueling at stopover sites, and increased again prior to departure. During spring migration in 2017, we examined Gray Catbirds (*Dumetella carolinensis*) on St. George Island, a Florida panhandle barrier island and first landfall site for many trans-Gulf migrants. We sought to test the predicted relationships among CORT, refueling rate, and body condition during stopover. We measured baseline CORT, body mass, plasma triglycerides, and precise body composition using a Quantitative Magnetic Resonance analyzer (QMR). We found that birds with low body-, fat-, and lean mass had higher baseline CORT levels. These data are consistent with the hypothesis that baseline CORT declines at stopovers as body condition improves. However, refueling rate (as indicated by plasma triglycerides) was not predicted by CORT. Our data were not able to detect an increase in baseline CORT prior to departure. This may be because Gray Catbirds don't stay long on the island, instead relocating to the mainland to continue their stopover phase. Feather deuterium values will be analyzed to clarify the migration destinations of these individuals and provide context to our findings.

P1-261 DETMERING, S/E*; MCMAHON, T/A; University of Tampa ; *sarahdetmering3@gmail.com*

The Effects of Bd Metabolites on Freshwater Invertebrates

Batrachochytrium dendrobatidis (Bd) is a fungus that is causing extinctions and extirpations of amphibians around the world. Bd is an aquatic fungus that attacks the keratin in the skin of amphibians and the carapace of some freshwater invertebrates, like crayfish. Bd metabolites have been shown to damage the gills of crayfish in the absence of live Bd, but little research is done in this field. Here, we investigated the effects of Bd metabolites, in the absence of Bd, on developing mosquitos and the bioindicator *Daphnia magna* . There is a negative relationship between Bd metabolite concentration (measured as the concentration of Bd removed from the inoculant) and Daphnia survival ($p= <0.01$), but there was no effect of Bd metabolites on mosquito mortality. The presence of Bd metabolites induced molting in *Daphnia* and mosquito larvae, which may have an impact on their development. Our findings indicate exposure to Bd contaminated water, even in the absence of direct contact with Bd may adversely affect some freshwater invertebrates.

141-5 DEVITZ, A-C*; RUBI, TL; DANTZER, B; University of Michigan; *dantzer@umich.edu*

Behavior and diet of white-footed mice along an ecological range expansion

Ecological range expansions occur when a species expands its geographic distribution and they are thought to be increasing in frequency due to rapid environmental change. Although shifts in the distribution of species may have important ecological and evolutionary consequences, less is known about the characteristics of individuals leading range expansions in addition to those traits contributing to the success of individuals that disperse to these new areas. Some studies have suggested that specific behavioral attributes may cause some individuals to be more likely to participate in range expansions or be more successful either during the range expansion or after they arrive to the novel area. During a 3-year field study, we characterized the behavior of white-footed mice (*Peromyscus leucopus*) along a range expansion gradient throughout Michigan by sampling populations of *P. leucopus* that differ in time since colonization. We used standardized behavioral trials to characterize their behavior (activity, exploration) and stable isotope analyses to quantify their dietary breadth. As a control group, we also quantified the behavior and diet of a congeneric species, deer mice (*Peromyscus maniculatus*), at each of our study sites along the range expansion gradient where they were available. Using these data, we examined if the behavior and isotopic niche of the range-expanding species (*P. leucopus*) was affected by time since colonization and if they differed from the resident species (*P. maniculatus*). We discuss our results in the context of other studies examining if dispersal is dependent upon animal personality and those examining if an "invader behavioral syndrome" exists.

P2-111 DEYARMIN, J.S.*; MCCORMLEY, M.C.; CHAMPAGNE, C.D.; STEPHAN, A.P; PUJADE BUSQUETA, L; CROCKER, D.E.; HOUSER, D.S.; KHUDYAKOV, J.I.; Univ. of the Pacific, Univ. of Washington Bothell, Sonoma State Univ., National Marine Mammal Foundation; *j_deyarmin@u.pacific.edu*

Distinct blubber proteome responses to single and repeated ACTH challenges in a marine mammal

Repeated or chronic stress, such as that caused by anthropogenic activity and environmental disturbance, may 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 stress biomarkers. 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 proteomics to examine changes in protein expression in the blubber of northern elephant seals *(Mirounga angustirostris)* in response to multiple stress challenges. 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 ("repeated") administrations. We isolated and sequenced the proteome and identified 8793 proteins in elephant seal blubber. Across the proteome, 46 KEGG pathways were enriched, such as carbon metabolism, glycolysis/gluconeogenesis, fatty acid degradation, and fatty acid metabolism. For differentially expressed proteins, we compared protein abundance across stress states using isobaric labeled tags. Proteins that were differentially in response to ACTH were associated with lipid binding, pentose phosphate pathway, lipid transfer, and other cell maintenance pathways. The stress markers identified in this study may be used to assess stress states in vulnerable marine mammal populations using targeted assays.

P2-30 DHAWANJEWAR, AS*; MEIKLEJOHN, CD; MONTOOTH, KL; University of Nebraska-Lincoln; *abhilesh.dhawanjewar@huskers.unl.edu*

Mitochondrial Diseases and Compensated Pathogenic Deviations

The epistatic effects of amino acid substitutions exert a strong influence on protein evolution trajectories. A substitution that is pathogenic in one genetic background may be neutral or even beneficial in the presence of other substitutions that interact with the pathogenic substitution. Many disease-associated missense mutations or ‘Pathogenic Deviations (PDs)' in humans are observed to occur as native, wild-type residues in other non- human species. This particular class of missense mutations is known as ‘Compensated Pathogenic Deviations (CPDs)' as in order to become fixed in the non-human species, their pathogenic effects must be compensated by one or more substitutions at other sites in the same protein or in an interacting protein. Defects of the mitochondrial respiratory chain are especially interesting as the respiratory chain is the only metabolic pathway in the cell controlled by both the mitochondrial and the nuclear DNA. To investigate the structural nature of these epistatic compensatory interactions, we identify PDs and CPDs from MITOMAP's database of human mitochondrial disease mutations and map them onto three- dimensional protein structure models. To further understand whether the nature of compensated mutations (CPDs) is different than that of uncompensated mutations (PDs), we examine several structural effects concerning protein stability as well as binding effects. We also compare and contrast the patterns observed in mitochondrial diseases with previous studies that primarily focused on diseases caused by mutations in the nuclear DNA.

S12-11 DHINOJWALA, A; NIEWIAROWSKI, PH*; University of Akron; *phn@uakron.edu*

Developing prototypes for testing gecko adhesion on rough surfaces

It has been nearly 20 years since Autumn and colleagues established the central role of van der Waals forces in how geckos stick. Much has been discovered about the structure and function of fibrillar adhesives in geckos and other taxa, and substantial success has been achieved in translating natural models into bioinspired synthetic adhesives. Nevertheless, synthetics still cannot match the multidimensional performance observed in the gecko system that is simultaneously robust to dirt and water, resilient over thousands of cycles, and competent on surfaces that are rough at drastically different length scales. Apparent insensitivity of adhesion to variability in roughness is particularly interesting from both a theoretical and applied perspective. Progress on understanding the extent to which and the basis of how the gecko system is robust to roughness is impeded by complexity of quantifying roughness of natural surfaces and a dearth of data on gecko substrate use. We review methods for characterizing rough surfaces as they relate to the potential for collecting relevant estimates of variation in gecko adhesive performance across different substrates in their natural habitats. Our goal is to suggest tractable and practical protocols to enable researchers to design detailed studies of structure-function relationships of the gecko fibrillar system that translate into its ability to deliver robust adhesion across large variation in roughness. Such data can help advance development of design parameters to improve bioinspired adhesives based on the gecko fibrillar system.

91-6 DI SANTO, V*; LAUDER, GV; Harvard University; *vdisanto@fas.harvard.edu*

Fish Schooling: Dynamic Shifts in School Structure with Swimming Speed and During Feeding

Schooling is a prevalent collective behavior exhibited by about 80% of all known fish species during at least some phases of their life. School formations are characterized by strong polarization, and fish maintain reasonably discrete relative positions within the group. Such behavior has been associated with a series of advantages ranging from enhanced capacity to reproduce to increased survival rates during predator attacks. A precise school pattern, where fish are evenly distributed in a phalanx or diamond configuration, is also thought to increase locomotor efficiency when compared to solitary fish, because individual fish may take advantage of the vortices shed by their neighbors during swimming. Here we present data on schooling behavior of a forage fish, the inland silverside (*Menidia beryllina*). We analyzed tridimensional schooling patterns and dynamics in fish swimming in a flow tank at different speeds, during and following disruptions caused by feeding events, and present preliminary results on the effect of climate-related stressors on school formation. Fish school volume is reduced and flattened as speed increases, and individual fish switch position at a higher frequency when they are forced to increase speed. Introduction of food induces the fish to quickly and temporarily leave the school formation to feed, and the precision of fish returning to their position within the school is also quantified. Comparison of data from different flow and feeding conditions suggests that schools are rarely static as individual fish do not maintain the same position within the school for an extended period, and the general shape of the formation morphs as the interactions between individual shift over time.

P1-48 DIAL, TR*; LAUDER, GV; Harvard University; *terrydial@fas.harvard.edu*

First-feeding prey capture: comparing zebrafish and guppies

Two prominent model fishes, zebrafish and guppies, produce tiny offspring (3.5-5.5 mm in length), yet guppies spend nearly an order of magnitude more time developing *in utero* prior to first feeding. Suction feeding at small size is thought to be constrained by the hydrodynamics of actuating small mouthparts quickly through a viscous medium. By manipulating water viscosity, we control the hydrodynamic regime (measured as Reynolds number, Re) to ask what effect developmental time has on offspring maturation, feeding performance and suction generation between these two species. Ossification rate is used as a measure of morphological maturation and was found to be similar between the two species: each species is 50% ossified at 7.25 mm in length. Despite that first feeding occurs prior to each species reaching even 10% maturity, capture success of suspended prey is significantly higher in guppies (90% vs. 20%). As Re increases, both species are able to capture prey at increasing distances, but at any given Re, guppies successfully feed at greater distances to prey. Both offspring generate negative pressures during a strike, but suction is simultaneously associated with ram feeding. Particle imaging shows that a bow wave leads the approaching zebrafish larvae, which pushes the prey item ahead of the mouth by 0.5 head length. During the suction event, the bow wave temporarily ceases, and the momentum of the larvae allows it to capture the stationary prey. An approaching guppy offspring also produces a bow wave, but due to greater oral jaw protrusion and lateral head expansion, the suction field generated by the guppy extends beyond the horizon of the bow wave. A larger suction field might allow guppy offspring to feed at greater distances and with higher success rates, but maturation of the skeletal system alone does not explain this observation.

69-4 DIAMOND, KM*; SCHOENFUSS, HL; BLOB, RW; Clemson Univ., St. Cloud State Univ.; *kmdiamo@g.clemson.edu*
Examining Patterns of Climbing and Escape Performance over Migration Pulses in the Hawaiian Goby Sicyopterus stimpsoni
Many animals incorporate migratory phases into their life history. Migrations often involve traversing treacherous habitats to reach environments that provide resources that promote fitness. However, when animals migrate in large groups, passage through such habitats may occur along a temporal gradient. In the Hawaiian Islands, migrations of the goby species *Sicyopterus stimpsoni* are stimulated by flash floods. Following a flood, a migration pulse ensues in which hordes of juveniles migrate from the ocean to upstream adult habitats. Along their migration path, fish must evade picivorous predators and climb waterfalls while swimming upstream against ambient stream flow. It is possible that performance in both of these variables may vary over the course of the migration pulse. To test this prediction, we collected fish across migration pulses lasting 2-6 days and measured their performance in both burst escape performance and climbing trials. Results suggest that escape performance is independent of migration timing, but that climbing performance is greatest among fish collected near the end of migration pulses. If fish with variable performance are able to reach adult habitats as a result of differential timing of migration, it could explain the genetic and morphological variation previously recorded among adult populations. Understanding when fish are most likely to succeed in migrations could also improve management decisions for the protection of migratory species.

11-2 DIAS, AS*; VON HAGEL, AA; SUMMERS, AP; GERRINGER, ME; FARINA, SC; Whitman College, Univ. of Washington, Seattle, Univ. of Washington, Friday Harbor, Univ. of Washington, Friday Harbor, Howard Univ.; *diasas@whitman.edu*
Evolution of bone density in deep-sea snailfishes
The family Liparidae, snailfishes, span the largest depth range of any marine fishes. The shallowest species can be found in tidepools of temperate zones, while hadal snailfishes, the deepest-living fishes, reside as deep as ~8,200 meters. Extreme environmental conditions—low temperature, high pressure, lack of light, limited food availability, and varying oxygen concentrations—exert evolutionary pressures on the organisms that inhabit the deep sea. Liparids do not have swim bladders and are mostly demersal, but the deepest species must maintain neutral buoyancy to spend time in the water column hunting for their sparse prey. Reduced bone density is another mechanism by which these species adapt to maintain buoyancy in the deep sea. We used micro computed tomography (micro-CT) scanning to study bone density across the full bathymetric range of the Liparidae, 32 species from 12 genera. Of these specimens, five bones were measured for density by calculating relative mean pixel brightness to hydroxyapatite phantoms: the lower jaw, for purposes of feeding mechanics; the third vertebrae, as a control; the first left pelvic pterygiophore, for studying the suction disk; the hypural plate, to study swimming and movement trends, and the sagittal otoliths. Taking into consideration the phylogeny of the specimens, we observed a decrease in bone density with increasing depth. The degree of change in density with depth differed among the structures that we measured, with evolutionary implications for functional performance of structures in the deep sea.

70-7 DIAZ, RE*; ROELLIG, D; BRONNER, M; TRAINOR, PA; Southeastern Louisiana University, California Institute of Technology, Stowers Institute for Medical Research; *lissamphibia@gmail.com*
From Climbing Trees to Phylogenetic Trees: Veiled Chameleons (Chamaeleo calyptratus) as a Squamate Model to Fill Our Evolutionary Gaps in Vertebrate Neural Crest Cell Induction, Migration and Differentiation.
Neural Crest Cells (NCC) are a migratory cell population that differentiates from along the dorsal and lateral margins of the forming embryonic central nervous system and contribute various cell types and tissues to the organismal body (such as cranial cartilage and bone, pericytes of the vasculature and pigment cells). While various subpopulations have been identified (cranial, cardiac, trunk, sacral) in groups with a longer history of study (i.e., established model organisms), not all vertebrate lineages have received equal attention. Within amniotes, ~33% of extant species are represented by the Lepidosauria (Rhynchocephalia [tuatara] + Squamata [snakes, lizards]), yet little work has been conducted on the NCC biology within this clade. Such a discrepancy in studies can be traced to the difficulty in examining NCC development in Lepidosauria as embryos in the majority of species examined begin development within the oviduct and, upon oviposition, embryos are at an advanced stage of morphogenesis (limb bud). Here we present the establishment of the Veiled Chameleon (*Chamaeleo calyptratus*) as a useful lepidosaur system for studying early embryonic development as embryos are at an early gastrula stage at egg laying and also present a slow rate of embryonic development (6 months) suitable for detailed examination of morphogenesis, thus allowing us to characterize NCC development, migration and differentiation in a squamate reptile.

P1-223 DIAZ, S*; DEANGELIS, D; Department of Biology, University of Miami, Wetland and Aquatic Research Center, US Geological Survey; *s.diaz12@miami.edu*
Development and Validation of a Spatially Explicit Individual-based Model for Simulating Savanna Elephant (Loxodonta africana)) Space Use
Understanding the spatiotemporal dynamics of elephant movement across landscapes is critical for effective conservation of elephant populations in southern Africa. Individual-based modeling can serve as a predictive tool, facilitating understanding of how future scenarios of landscape change may impact elephant movement dynamics. We developed a spatially explicit individual-based model (IBM) to simulate space use for savanna elephants in Chobe National Park (CNP). Known external and internal drivers of elephant movement are linked to the external environment through behavior-based movement rules, and movement within the model's environment results from the agent interacting with various landscape attributes. Characteristics of elephant movement patterns, including home range size, total daily displacement distances, and net daily displacement distances, were identified for model validation. Sixty trajectories were simulated for CNP's wet season and compared to a similar number of empirical trajectories. The distributions of simulated and empirical home range sizes are not significantly different, indicating good agreement between model outputs and real-world home range sizes. Conversely, there is a significant difference in the distribution of total distances traveled daily and net daily displacements calculated from simulated and empirical trajectories. Ongoing work sets out to understand the reasons for the discrepancies between model and empirical movement characteristics and modify model parameters to improve the IBM's ability to project movement patterns observed in nature. The validated IBM will then be used to explore how various scenarios of landscape change, including changes in surface water availability, may influence elephant space use.

31-1 DIAZ, C*; TANIKAWA, A; MIYASHITA, T; MAKSUTA, D; AMARPURI, G; DHINOJWALA, A; BLACKLEDGE, T; University of Akron, Akron, University of Tokyo, Tokyo; *candido.diaz.jr@gmail.com*

The Moth Specialist Spider Cyrtarachne akirai Uses Prey Scales To Increase Adhesion

Contaminants decrease adhesive strength by interfering with substrate contact. Spider webs adhering to moths present an ideal model to investigate how adhesives overcome contamination because moth's sacrificial layer of scales rub off on sticky silk, allowing the moths to escape. The Cyrtarachninae spiders evolved webs that overcome this limitation and are moth-specialists. We compare the adhesive performance of *Cyrtarachne* glue to more typical spider glues to understand how *Cyrtarachne* glue overcomes dirty surfaces. High-speed videos show that upon contact with moth-wings the low viscosity of *Cyrtarachne* aggregate glue allows it to seep beneath the scales and accelerate, spreading along the underlying cuticle due to capillary forces. The adhesive strength of most other spiders' glues is maximized at a much higher viscosity that optimizes the contributions of spreading for surface contact versus cohesive strength. While the low viscosity of *Cyrtarachne* glue leads to rapid spreading how does it not sacrifice cohesive strength of the glue? Infrared spectroscopy showed a rapid loss of unbound water during initial spreading which may indicate drying of the droplet. Raman spectroscopy and optical microscopy support that the distribution of glycoproteins and salts is not homogeneous as found in other spider species. Instead, we hypothesize that rapid spreading of the liquid components of the glue relative to adhesive material leads to localized drying, increasing cohesive strength.

41-1 DIAZ, K*; SCHIEBEL, PE; DING, JL; LU, H; GOLDMAN, DI; Georgia Tech; *kelimar.diaz@gatech.edu*

Undulatory Locomotion in Heterogeneous Environments Across Scales

Undulatory locomotion is ubiquitous across scales. A well-studied system is the nematode *C. elegans*, which moves through propagation of dorsoventral waves of body curvature. Surprisingly few studies have focused on the worm's control of these waves to generate effective interactions in its natural environment (e.g. rotting fruit). In contrast, progress has been made in discovery of control principles in undulatory macroscopic systems (e.g. snakes, snake-like robots) that move in complex terrain. We posit that environmental interactions from frictional/yielding surfaces and rigid heterogeneities are similar in dissipative macroscopic and microscopic systems. To discover if similar control principles for undulatory locomotion in heterogeneous landscapes exist across scales, we studied a habitat generalist snake, *P. guttatus*, a desert specialist snake, *C. occipitalis*, and the mm-long *C. elegans* traversing sparse lattices of rigid cylindrical posts, a model of heterogeneous terrain. Snakes were tested in hexagonal arrays of 0.64 cm diameter posts on a low-friction board. Unlike *P. guttatus* which modulates body shape to generate appropriate reaction forces using the posts, *C. occipitalis* adheres to a simple wave which we hypothesize generates propulsion via a random but opportunistic post use. Experiments on *C. elegans*, conducted in fluid-filled PDMS lattices of comparable scaled dimensions, revealed that the worm used a strategy similar to *C. occipitalis*, leading to bouts of effective locomotion interspersed with periods of large slip. Without post-contact *C. elegans* and *C. occipitalis* moved at ~0.2 body lengths per undulation cycle (BL/cyc); when contacting the posts both snakes and worms moved at ~0.35 BL/cyc, indicating similarities in task-level control.

12-4 DICK, MF; ALCANTARA-TANGONAN, A; OGHLI, YS; WELCH, KC*; University of Toronto Scarborough; *kwelch@utsc.utoronto.ca*

Now or Later: Differential fates for glucose and fructose in a nectarivore

Hummingbirds fuel their high energy needs with the fructose and glucose in their nectar diets. These sugars are used to fuel both immediate energy needs and to build fat stores to fuel future fasting periods. Most studied vertebrates are relatively adepts at utilizing ingested glucose for energy in most tissues, while fructose is largely metabolized by splanchnic tissues. If and how hummingbirds partition dietary fructose and glucose towards immediate oxidation to fuel foraging behaviour or fat storage is unknown. Using a chronic stable isotope tracer methodology we examined if glucose or fructose are preferentially used for de novo lipogenesis in ruby-throated hummingbirds (Archilochus colubris). Ruby-throated hummingbirds were fed diets with the glucose or fructose enriched with ^{13}C for 5 days and we measured isotope incorporation into fat via the breath $^{13}CO_2$ signature while fasting (oxiding fat) to trace incorporation into adipose stores. We found higher incorporation of stable isotopes into the fat stores when glucose was enriched compared to fructose suggesting preference for glucose as a substrate for fatty acid synthesis. However, we noted that the apparent turnover of the fat pool in hummingbirds was much slower (t_{50}= 87 h) than that reported in other small vertebrates. To test if this was related to time spent in captivity, we repeated the study with newly caught hummingbirds and found a similar preference for glucose. We also observed a ~70% faster fat turnover in freshly caught birds. The faster rate was significantly correlated to lower body mass (r=0.87, p<0.001) and higher nectar intake (p=0.006). This suggests that there are profound changes to daily energetics in long-term captive individuals relative to their wild counterparts.

12-3 DICK, MF*; WELCH, KC; University of Toronto; *morag.dick@utoronto.ca*

Dietary guild influences sugar oxidation in bats

Bat species in the Phyllostomidae family evolved from a common insectivorous ancestor to eat a variety of diets. Evolutionary changes in a species' diet are accompanied with changes in digestive physiology, including increasing sucrase activity in frugivores and nectivores, and loss of sucrase in sanguivores. Additionally, bats must also meet the high energy requirements of flight, and nectarivores can fuel flight almost exclusively using recently ingested sucrose, glucose or fructose. This feat is not only due to efficient digestion and absorption in bats, but also due to post-absorptive adaptations to increase sugar oxidation to directly fuel their metabolism. However, species-specific adaptations to sugar oxidation have not been investigated. We examined whether capacity for oxidation of sucrose and its components glucose and fructose vary among dietary guilds. We used a carbon stable isotope breath tracer technique to non-invasively monitor the oxidation of ^{13}C enriched sugars (glucose, fructose, and sucrose) over 90 mins using through their breath stable isotope signature. Insectivorous bats had overall lower oxidation rates and no effect of sugar type. In comparison, the lack of sucrase enzyme in vampire bats (*Desmodous rotundus*) precludes the breakdown of sucrose, preventing its absorption and oxidization. Frugivorous and nectarivorous species had overall higher oxidation rates, with fructose reaching peak oxidation faster. Since glucose and fructose are both partially absorbed through paracellular absorption in bats, the rapid and high rate of fructose absorption could be due to post-absorption adaptions rather than absorption rates. Overall, this study supports known differences in intestinal enzymes, but also suggests additional species-specific adaptations in the oxidation of sugars in bats.

S1-9 DIGGLE, Pamela*; MULDER, Christa; University of Connecticut, Storrs, University of Alaska, Fairbanks; *pamela.diggle@uconn.edu*

Does Variation in Flower Development Explain Anomalous Phenological Responses to Temperature?

Climate change has resulted in increased temperatures across the globe. Although many angiosperms flower earlier in response to rising temperature, a substantial number of species either do not appear to respond or even delay flowering in, or following, warm years. Existing phenological models cannot explain such exceptions to the common association of advancing phenologies with warming temperatures. The phenological events that are typically recorded (e.g., onset of flowering) are but one phase in a complex developmental process that often begins one or more years previously, and flowering time may be strongly influenced by temperature over the entire multi-year course of flower development. Preformation, the initiation of flower primordia one or more years prior to anthesis, is characteristic of temperate forest trees, shrubs, and many herbaceous perennials, and ubiquitous for high elevation and high latitude species. We explore conceptual models of the effects of temperature on the entire year-long process of flower preformation that incorporates changes in developmental rates, timing of onset and offset of individual stages, as well as plant and inflorescence architecture. Understanding these developmental process could dramatically improve our ability to predict the timing of flowering in temperate environments and may also give insights into how temperate trees and shrubs, the majority of which preform flowers, will respond as the climate continues to warm.

26-7 DILLON, ME*; WOODS, HA; PINCEBOURDE, S; Univ. or Wyoming, Univ. of Montana, Univ. of Tours, France; *Michael.Dillon@uwyo.edu*

Sampling frequency in thermal ecology: Do missed extremes and interpolated means matter?

The thermal relations between ectotherms and their environments determine body temperature, which is, in turn, a fundamental driver of physiology, life history, and ecology. Measuring responses of ectotherms to spatial and temporal variation in temperature is therefore a key goal of thermal ecology, particularly in the context of ongoing global climate change. Despite the potentially striking effects of short-term (seconds to minutes) temperature variation on ectotherms, most studies make inferences based on monthly or, at best, daily temperature measurements. Is higher frequency temperature variation noise that can be ignored? Or are we missing critical temperature effects and biasing inferences by discarding this "noise"? To determine the effects of changes in sampling frequency on ectotherm thermal ecology, we deployed operative models of insects of three size classes (2, 6, and 15 mm diameter spheres) on leaf surfaces and sampled model and air temperatures every second. We then subsampled these data and estimated the change in extreme temperatures, in exposure time, and in fitness (integrated from thermal performance curves). We found little change in estimates of extreme temperatures at sampling periods up to 30 min, with sampling periods 1 h or longer resulting in underestimates of extreme temperatures and of performance. The common approach of implicitly assuming a stair-step interpolation between distantly sampled temperatures overestimates exposure time to extreme temperatures. These findings suggest that even daily temperature measurements (which are often considered high frequency) are too coarse for making accurate inferences about the thermal ecology of small ectotherms.

P3-120 DILTS, S*; SARAJLIC, D; JUDD, ET; HATLE, JD; PATERSON, C; Univ. of North Florida, Agios Pharmaceuticals, Florida State College at Jacksonville; *jhatle@unf.edu*

Inhibition of hydrogen sulfide production by fat body of lubber grasshoppers

Cellular hydrogen sulfide (H_2S) is a gasotransmitter (like nitric oxide) required for life-extension by dietary restriction in mice. H_2S protects vasculature in mammals. In nematodes, H_2S exposure increases thermotolerance and lifespan. In insects, the production of H_2S by *Drosophila* fed life-extending, low-methionine diets is greater than production on full diets. Together, this suggests increased H_2S production is salubrious for invertebrates. Nonetheless, insects are often said to be ‘weak producers'. Here, we provide preliminary evidence for inhibition of H_2S production by lysates of grasshopper fat body. Fat body is analogous to liver, the most strongly producing tissue in mice. We tested production of H_2S using an enzyme activity assay. Lysates were incubated with cysteine and vitamin B6; produced H_2S was detected using lead acetate, which in the presence of H_2S makes the brown precipitate lead sulfide. Surprisingly, higher concentrations (50 ul, median of ~8 mg protein) of fat body lysate consistently produced less H_2S than did lower concentrations (0.69 mg protein). Decreasing the protein amount below 0.69 mg reduced H_2S production in a dose-dependent fashion. We next tested whether fat body lysate would inhibit production of H_2S by homogenates of mouse liver. Indeed, increasing concentrations of fat body lysate tended to decrease H_2S production by mouse liver homogenate (n=19; P=0.075). In contrast to this inhibition by grasshopper fat body, lysates of mealworms did not inhibit production of H_2S by mouse liver homogenate. These data suggest that a component of the lysate of grasshopper fat body, when present at higher concentrations, inhibits enzymatic production of H_2S by liver homogenates.

55-5 DIMOS, B*; MYDLARZ, L; PELLEGRINO, M; University of Texas at Arlington; *bradford.dimos@uta.edu*

Characterization of a novel stress resistance pathway in corals: The Mitochondrial Unfolded Protein Response

Coral reefs have experienced precipitous declines during the Anthropocene, in large part due to coral diseases and hyperthermic bleaching, which is the loss of the obligate algal symbiont. Intense research efforts have been undertaken to establish links between coral pathologies and cellular mechanics. Up to now the intermediary cellular pathways linking the coral host's response to heat and pathogen stress have not been functionally validated. A recently characterized cellular pathway, the mitochondrial unfolded protein response (mt^{UPR}) is a potent pro-survival mechanism mediating a wide array of effector responses. The key pathways up-regulated by the mt^{UPR} known to be important in coral stress responses include: antioxidant elements, heat shock proteins and anti-microbial compounds. Up to now the mt^{UPR} has only been investigated in humans and the model nematode *Caenorhabditis elegans* (*C. elegans*) for its role in numerous human diseases. In the first study to utilize transgenesis in corals, we validated the existence of the mt^{UPR} in *Orbicella faveolata* (*O. faveolata*) mediated by the coral cyclic AMP-dependent Activating Transcription Factor 5 (cATF5). Microinjection of the cATF5 gene construct was able to rescue a genetic knockout model of *C. elegans* harboring a mt^{UPR} reporter construct. cATF5 was demonstrated to be up-regulated during both temperature and pathogenic stress in *O. faveolata*. Using qPCR and bioinformatic methods we were able to demonstrate the coral mt^{UPR} shares functional homology to the human and *C. elegans* mt^{UPR}, by being able to increase transcription of Heat Shock proteins 60 and 70, as well as superoxide dismutase. This pathway has the potential to enhance understanding of coral stress responses at the cellular level in a changing climate.

P3-13 DINGWALL, HL*; GRINSTEIN, M; CAPELLINI, TD; GALLOWAY, JL; Harvard University, Massachusetts General Hospital, Harvard University, Massachusetts General Hospital ; *hdingwall@fas.harvard.edu*

Transcriptomics of postnatal tendon growth

Tendon size can vary widely among closely related taxa, e.g. mice vs. jerboas, suggesting that the tendons of these species may experience different growth regimes. In mice, the period from birth to roughly 1 month of age is characterized by extensive tendon growth. Conventional wisdom states that this growth is driven by expansion of the extracellular matrix with negligible cell proliferation. However, our previous work has shown that tendon cells remain proliferative through postnatal day (P) 14, after matrix production has already begun to increase. Thus, this period is a time of dynamic change within the tendon, but the molecular mechanisms governing these transitions are largely unknown. We performed RNA sequencing on mouse tendons sampled weekly from P0 to P35 to identify transcriptomic signatures associated with the changing cell proliferation dynamics. Approximately 22% of detected genes were found to be differentially expressed (DE) at some point during the time series (adj. $p < 0.01$). To gain a more detailed understanding of temporal gene expression patterns during this period, we subset all DE genes by fitting observed counts to different models of expression over time. Gene Ontology and Gene Set Enrichment Analyses of these subsets suggest that biological processes involved in cell proliferation and differentiation dominate the earlier time points, while cell communication and cytoskeleton organization become more important later. The midpoint of this time series exhibits upregulation of genes involved in the secretion and binding of extracellular matrix, but downregulation of molecules that control cell adhesion. These results suggest that postnatal tendon growth involves three stages: the proliferative phase, matrix secretory phase, and organization phase.

1-5 DINH, JP*; NOWICKI, S; PETERS, S; Duke University; *jpd29@duke.edu*

Intra-diel improvement in song performance: swamp sparrows 'warm up' in the morning

Index signals convey reliable information about a signaler's quality because they are constrained by the signaler's anatomy or physiology. 'Vocal performance' in birdsong may be considered an index signal to the extent that certain acoustic features of song are limited by the singer's vocal capabilities. Many species of birds exhibit a dawn chorus, a period of especially active singing occurring at first light, after which singing becomes relatively less frequent. One hypothesis predicts that birds use dawn choruses to 'warm up,' much like human athletes or musicians do, to maximize their vocal performance for the rest of the day. We tested this idea in swamp sparrows (*Melospiza georgiana*), a species for which the underlying biomechanical constraints on vocal performance are especially well-known and in which the behavioral significance of vocal performance also has been well-studied. We analyzed 1301 songs from a cohort of 11 captive swamp sparrows over the course of 2 days and measured changes in vocal performance across the day. We found that song performance is positively correlated with time of day, suggesting that swamp sparrows do warm up throughout the morning. However, song performance was not correlated with the absolute number of songs that a bird had sung previously in a morning. The performance benefit associated with vocal warm-up may explain why songbirds engage in a dawn chorus to the extent that vocal performance correlates positively with the amount of time a bird has sung. Our finding that the number of previously performed songs does not predict vocal performance suggests that songbirds may experience fatigue of the vocal apparatus, thereby imposing an upper constraint on the optimum number of songs a bird should produce during a single morning.

P2-32 DIORIO, R.A.*; HOWEY, C.A.F.; University of Scranton; *raymond.diorio@scranton.edu*

Does Substrate Type Affect Scent-trailing Behavior of Adult and Newborn Timber Rattlesnakes?

Animals can obtain social information from monitoring chemical cues within their environment left behind by conspecifics, competitors, predators, or prey. Whereas many studies have addressed the ability for snakes to trail scents within a laboratory along a homogenous substrate (typically butcher paper), our objective was to determine if the scent-trailing behavior of a snake was affected by changes in substrate type. In our first experiment, we brought 5 gravid timber rattlesnakes (*Crotalus horridus*) into the laboratory where each gave birth to an average 9 neonates. After each neonate shed, we conducted Y-maze trials. For each trial, the Y-maze floor was covered in either paper, sand, leaf litter, or burnt leaf litter. The scent of the mother was applied down one arm of the Y-maze. Prior to each trial, we replaced the substrate and scent. Each neonate was tested on each substrate. Neonates non-randomly chose the arm with the mother's scent 87% of the time when tested on paper ($P < 0.001$) and 73% of the time when tested on sand ($P < 0.011$). When tested on leaf litter and burnt leaf litter, neonates chose the arm with the mother's scent 67% and 53% of the time ($P < 0.068$ and $P < 0.715$ respectively). Substrate affects the ability for neonates to scent trail their mother. In our second experiment, we brought adult male *C. horridus* into the laboratory and repeated Y-maze trials; replacing the mother's scent with the scent of freshly struck and envenomated mouse. We will discuss preliminary results of the second experiment and how they compare to neonate trials. In a natural setting, the mosaic of substrates may facilitate scent-trailing behavior. However, as prescribed fire becomes a more popular forest management tool, care should be taken in where this tool is applied given that it may affect scent-trailing behaviors.

P1-66 DIPAOLO, EC*; MEHTA, RS; COLLAR, DC; Christopher Newport University, Univ. of California, Santa Cruz, Phi Mu; *emma.dipaolo.14@cnu.edu*

Cascading Anatomical Evolution Drives Body Elongation in Clinoid Blennies

Major transformations in body shape punctuate the evolutionary history of ray-finned fishes. Eel-like or torpedo-shaped fishes emerge, sometimes rapidly, from lineages that are otherwise made up of fusiform or shorter-bodied species. These transitions in shape may result from different combinations of changes in anatomical features spread across the body, but it is unknown whether these changes emerge in a correlated manner or if they accrue in series over time. In this study, we measure dimensions of the body, skull, and vertebral regions for species of blenniiform fishes and use phylogenetic methods to identify exceptionally rapid evolution of elongated body shape in a blenniiform subclade that includes the pikeblenny (*Chaenopsis alepidota*) and arrow blenny (*Lucayablennius zingaro*). Major shape transformation began in the shared ancestral lineage of these species (i.e., their stem lineage) as the skull elongated and body depth decreased. After splitting from this ancestor, these species continued to elongate, but they followed different evolutionary trajectories. Transformation in the arrow blenny was achieved by elongating the head, whereas the pikeblenny lengthened the caudal region by greatly increasing vertebral numbers. Overall, our results reveal a major body shape transformation—eel-like blennies—that arose because of cascading anatomical changes spread across multiple ancestral lineages, perhaps as a result of adoption of a novel ambush-style predation followed by divergence in dietary niche.

P1-249 DIXON, G*; KITANO, J; KIRKPATRICK, M; University of Texas, Austin, National Institute of Genetics, Mishima, Shizuoka, Japan; *grovesdixon@gmail.com*

Origin of a new sex chromosome by introgression between sticklebacks

Introgression is increasingly recognized as a source of genetic diversity that fuels adaptation. Its role in the evolution of sex chromosomes, however, is not well known. Here we confirm the hypothesis that the Y chromosome in the ninespine stickleback, *Pungitius pungitius*, was established by introgression from the Amur stickleback, *P. sinensis*. Using whole genome resequencing, we identified a large region of Chr 12 in *P. pungitius* that is diverged between males and females. The region of differentiation falls within an inversion, which appears to prevent recombination between the chromosomes. Population genetic and phylogenetic analyses show that within this inversion, the Y chromosome of *P. pungitius* shares a most recent common ancestor not with the X chromosome, but with the homologous chromosome in *P. sinensis*. Our findings indicate that porous species boundaries can trigger rapid sex chromosome evolution.

4-4 DIXON, G*; BAY, LK; MATZ, MV; University of Texas, Austin, 2Australian Institute of Marine Science, PMB 3, Townsville, Queensland 4810, Australia; *grovesdixon@gmail.com*

Role of gene body methylation in coral acclimatization and adaptation

Gene body methylation (GBM) has been hypothesized to modulate responses to environmental change, including transgenerational plasticity, but the evidence thus far has been lacking. Here we show that coral fragments reciprocally transplanted between two distant reefs respond with genome-wide increase or decrease in GBM disparity among genes. Surprisingly, this simple genome-wide adjustment predicted broad-scale gene expression changes and fragments' fitness in the new environment. This supports GBM's role in acclimatization, which may consist in modulating the expression balance between environmentally-responsive and housekeeping genes. At the same time, constitutive differences in GBM between populations did not align with plastic GBM changes upon transplantation and were mostly observed among F_{ST} outliers, indicating that they arose through genetic divergence rather than through transgenerational inheritance of acquired GBM states.

64-8 DIZON, RN*; SOLIS, AJ; BARNES, CJ; ISAACS, MR; HARRIS, SL; LEE, DV; University of Nevada-Las Vegas; *dizonr1@unlv.nevada.edu*

A robotic platform to test control strategies for bipedal walking

We use a simple walking robot, referred to as a Dynamic Control Platform (DCP) to investigate algorithms for the control of bipedal walking. Our control strategies target orthogonal constraint — a perpendicular relationship between the center of mass velocity vector and ground reaction force vector. This is done by actuating the ‘ankle' joint to achieve braking or propulsion and thereby modulate the direction of the ground reaction force vector. The ‘ankles' are driven by DC gear motors through a belt-pulley system and the symmetrical heel and toe extensions of the foot are scaled to the length of a human foot. A force-instrumented trackway provides inputs via Wi-Fi to the control system on-board the robot. Deviation from orthogonal constraint is determined each millisecond in by 1) calculating the ground reaction force vector and 2) integrating the resulting acceleration to determine the velocity vector. We use **mechanical cost analysis** to analyze the walking dynamics of the DCP in comparison to human walking dynamics. This analysis determines the mechanical cost of transport (CoT_{mech}) of a walking stride, as well individual instances of high and low cost throughout the single and double stance phases of walking. While humans show appreciable mechanical cost in both phases of the stride, comparable measurements have not yet been made on a walking robot. We explore constraints and solutions with respect to this cost profile to inform the mechanism and control of bipedal walking. Control algorithms developed in the DPC can reveal new strategies for bipedal walking gaits in robots, interpret effects of foot length, compliance or other mechanical properties, and improve the function of powered prosthetics or exoskeletons.

36-4 DO AMARAL, MCF*; DUFRESNE, S; GOINES, B; TEGGE, Z; KRANE, CK; Mount St. Joseph University, University of Dayton; *clara.doamaral@msj.edu*

Cryoprotectant Production in the Freeze-Tolerant Cope's Gray Treefrog (Dryophytes chrysoscelis): Effect of Acclimatization on Hepatic Enzyme Activity

Cope's gray treefrog, *Dryophytes chrysoscelis*, is one of few anurans found in North America that can survive the low temperatures of winter by tolerating freezing of its body fluids. Freezing survival can be achieved, in part, by production and accumulation of cryoprotectants: low molecular weight compounds that minimize the physical, biochemical, and molecular challenges associated with internal ice formation. *Dryophytes chrysoscelis* not only accumulates glycerol and glucose as cryoprotectants, but has also recently been shown to accumulate urea. While production of glucose in *D. chrysoscelis* is usually induced by freezing, production of glycerol and urea can be induced by low temperature exposure. Although recent studies suggest a role for hepatic glycogen as a source for cryoprotective glycerol and glucose, the source and mechanism involved in anticipatory accumulation of glycerol and urea is not understood. In this study we determined how cryoprotectant levels and the activity of hepatic glycerol-3-phosphate dehydrogenase, aspartate aminotransferase, and alanine aminotransferase changed in summer, fall, and winter frogs, as well as animals exposed to dehydrating conditions. Our results further elucidate the contribution of carbohydrates and amino acids to the cryoprotectant pool, and the role of acclimatization to the development of freeze tolerance.

P2-4 DOBKOWSKI, KA*; FLANAGAN, KD; CROFTS, SB; DETHIER, MN; Bates College; Friday Harbor Labs, Friday Harbor Labs, University of Illinois, Urbana/Champaign, University of Washington; Friday Harbor Labs; *kdobkows@bates.edu*

Ecology and scaling of juvenile bull kelp (Nereocystis luetkeana)

Bull kelp (*Nereocystis luetkeana*) is the dominant subtidal canopy architect in the Salish Sea, providing important habitat for many species and supplying primary production to food webs within and below the photic zone. Like other kelp, *N. luetkeana* has a complicated life history, alternating between microscopic (zoospore, gametophyte) and macroscopic stages; unlike many other kelps, it is an annual that must complete its lifecycle within a single year. Focusing primarily on juvenile bull kelp (sporophyte, stipe < 30 cm), we investigated the effects of competition and propagule availability on sporophyte appearance in a factorial-design subtidal field experiment. In the lab, we quantified differences of morphological scaling and material properties as well as the effects of temperature on the microscopic zoospore, gametophyte, and sporophyte stages. Our results indicate that bull kelp are probably not propagule-limited at our study sites and competition from understory species is the most important factor determining where juvenile bull kelp sporophytes grow and persist, with some variability in initiation of growth between plots established in different seasons. We also calculate a "breakpoint" between juvenile and adult morphological scaling. Additionally, we show that increasing temperatures may limit zoospore settlement and transitions between microscopic life stages, which has important implications for the fate of this foundation species, and the communities it structures, as global ocean conditions change. Our findings also highlight the importance of studying organisms with complex life histories across multiple stages because of the different factors that dictate their success across ontogeny.

P3-149 DODSON, AN*; OUTOMURO, D; WIATR, A; MOREHOUSE, NI; University of Cincinnati, Purdue University; *dodsonas@mail.uc.edu*

Motley views: Investigating the importance of receiver vantage point in shaping the appearance of a myrmecomorph spider

Animals must manage complex audiences comprised of predators, prey, and conspecifics, each with distinct sensory capabilities. Imperfect mimicry may result from compromises to maximize deception or detection among these multiple viewers. But how do mimics avoid predators while still capturing the attention of potential conspecific mates? One possibility is that morphology perceived by different viewers is dependent on their vantage points, allowing individuals to tailor their appearance to different audiences based on viewer perspective. We tested this idea in *Synemosyna formica*, a jumping spider ant mimic that must manage the responses of conspecifics, ants, and predators such as mantids, birds, wasps, and other spiders. Using high resolution images and elliptical Fourier analysis, we compared dorsal and lateral shapes of *S. formica*, other co-occurring spiders, and two co-occurring ants. We found that *S. formica* is closest in morphospace to ants, while sympatric spiders share less morphological similarity with ants. We also found the degree of similarity between *S. formica* and ant models varied between dorsal and lateral perspectives. Spectral data was collected from corresponding points on the bodies of *S. formica*, co-occurring spiders, and ants. Data were compared through visual models of sympatric predators and ants. We found that *S. formica* and ant spectra overlap in color and brightness while other spiders have less similarity to the ant models. The differences in morphology based on perspective and the similarities in *S. formica* and ant coloration indicate that audience perspective may play a role in shaping mimic morphology. Additionally, we found that juvenile and adult *S. formica* differ in which ant model they most closely resemble, indicating a possible shift in models across development.

12-6 DOLAN, JE*; HAMMOND, KA; UC Riverside; *jdola001@ucr.edu*

Sustained Metabolic Rates of Wheel Running in High Altitude Deer Mice

Animals living in extreme environments must be able to accommodate any associated increased energy demands. High altitude is one such environment that includes stressors such as hypoxia. Most studies have emphasized the max (VO_2max) and min (BMR) energy expenditures. VO_2max is measured with forced exercise while BMR is measured under conditions rarely measured in nature. However, the effects of normal and voluntary activity are often ignored in controlled laboratory studies using captive animals. To understand the effects of normal and ‘preferred' activity in caged animal systems, our study examines the costs of voluntary wheel running at both high and low altitude in deer mice (*Peromsycus maniculatus*). We wondered how voluntary activity might change to accommodate the physiological costs of hypoxia or other physiological parameters. To do this we measured the sustained metabolic rate (SusMR; kJ/day) of mice with and without wheels, wheel running activity and other physiological variables in deer mice both at low altitude and recently (< 4 days) moved to high altitude. We found that the SusMR was 59% higher in mice at high altitude (regardless of whether they had wheels). Likewise, mice with wheels have a SusMR that is 13% higher than mice without wheels (regardless of altitude). However, mice recently introduced to high altitude with wheels ran 13% less and had a VO_2max that was 13% lower than mice at low altitude with wheels; thus, there appears to be a trade-off between energy costs and voluntary activity for the mice recently moved to higher altitudes. Previous studies have shown that the deficit between VO_2max at low and high altitudes is regained after 8 weeks of acclimation. We will discuss the effects of recent and long-term hypoxia on SusMR as well as other aspects of deer mouse physiology.

92-3 DOMAN, TJJ*; BHANDAWAT, V; Duke University; *tjd37@duke.edu*

A New Behavioral Paradigm to Explore Idiothetic Cues in Navigation by Drosophila

Animals, including *Drosophila Melanogaster* (fruit flies), can keep track of their position using both cues generated by its movement (idiothetic cues), as well as external cues such as a landmark movement (allothetic cues). How fruit flies use allothetic cues such as vision and mechanosensory cues is relatively well understood. However, their ability to navigate based on idiothetic cues is underexplored. Therefore, we created a new behavioral paradigm to explore the use of idiothetic cues in navigation. In this behavior, a group of olfactory neurons which signal the presence of an attractive odor are optogenetically activated (using a red light) in a small region of the arena. Activation of the olfactory neurons result in the flies repeatedly visiting the location where the neurons are activated. By employing different arena sizes, different spatio-temporal configuration of the activation-zone we were able to understand the capacity of the flies to navigate using idiothetic cues alone. To further understand the principles underlying this navigation, we have replicated the same experimental design using a tethered fly on a trackball. Using its fictive trajectory, we will activate the same group of olfactory neurons when it is at a given position. A comparison of its performance on the trackball versus in freely walking animals will provide further insight into this problem. Finally, we will compare the search kinematics of flies in the ring assay to that of the flies on the trackball to determine the locomotive alterations of the searching fly while walking on a trackball.

P1-10 DOMENECH, S*; LAFOND, B; LONG, M; SELIGMAN, C; GILCHRIST, S; New College of Florida; *gilchrist@ncf.edu*

Implementing High Impact Practices in a Study Abroad Program at Cayos Cochinos, Honduras

High Impact Practices (HIPs) are important in encouraging students to pursue STEM careers. Study abroad can be used as an intensive time for students to learn practices of science including experimental design, field etiquette, and scientific communication. In this 5 week program, students spend three weeks on sight at Cayos Cochinos where they learn field skills to implement with their own mini projects. A student who participated the previous year acts as a teaching assistant to help with reef surveys and with implementing projects. Students are required to submit a series of essays along with the final project. In addition, students maintain a science blog to document their activities. The final presentation is a powerpoint with a voice component. Prior to completing the project, students make presentations to get feedback from the instructor and peers.

103-2 DONATELLI, CM*; SHEN, TH; KHANNA, S; TYTELL, ED; Tufts University, Columbia University; *cassandra.donatelli@tufts.edu*

The hydrodynamics of tail twisting during swimming in the American Eel (Anguilla rostrata)

Many fishes use body-caudal undulation to navigate their environments. Some fish, traditionally called anguilliform swimmers, use more than two thirds of their bodies to produce thrust. The hydrodynamics of these anguilliform swimmers has been well characterized and modeled by biologists, mathematicians, and engineers, but primarily focusing on flows in the horizontal plane. Some of the more recent characterizations have used conventional particle image velocimetry (PIV) methods to characterize the wake, showing that elongate fishes such as eels shed vortices which produce lateral jets along the length of the body and in the wake. Though these studies are comprehensive in 2D, we have not yet looked at the 3D motion of the body and tail. We know that as a 2D lateral bending wave passes down the body, a 3D torsional wave follows. In this study, we characterize flow around the body that results from that torsional wave in the American eel (*Anguilla rostrata*). We use a transverse PIV setup, in which the light sheet is perpendicular to the swimming direction. We find that as the tail beats and twists back and forth, two vortices are produced, one from the dorsal surface and one from the ventral surface. These vortices are likely part of the vortex loops shed as a result of the bending wave, and produce an upwards jet against the tail. The jet could indicate a lift force on the body, which may to cause the figure-eight pattern seen when looking at the tail from behind. It may also serve to lift the negatively buoyant fish off the ground, reducing fraction with the sediment and allowing the fish to move more easily through the water. This mechanism may be important in other negatively buoyant fishes as well, especially those with reduced pectoral fins.

47-7 DONG, G*; MITCHELL, D; MOSS, A; Auburn University, Auburn, AL ; *GZD0010@auburn.edu*

The structure and electrical activity of the tentacular apparatus of adult Mnemiopsis leidyi

Ctenophores have recently attracted much attention because several multigenetic molecular analyses proposed Phylum Ctenophora to be the sister taxon to all other animals. The common Western Atlantic ctenophore *Mnemiopsis leidyi* is currently the object of intense ecological and physiological study. The tentacular apparatus of ctenophores is critical to feeding and very likely bears a diversity of sensory functions. Previous studies of the cydippid *Pleurobrachia pileus* suggest that the tentacular bulb is an integrative center for afferent signals arising from the distal tentacle and a cell proliferation zone. The tentacular apparatus of adult cydippid and lobate ctenophores are superficially similar but as we show here, are morphologically distinct. Here, we use correlative light and electron microscopy in conjunction with fine extracellular probe recording to demonstrate structure/function relationships within the *M. leidyi* tentacular bulb. We generated the general scheme of the tentacular apparatus, showing the arrangement of tentilla and tentacular bulb. Bundles of hundreds of tentilla arise from the center of the bulb, indicating the location of the formation of the tentilla. Many tentillae were found connected to the aboral end the tentacular bulb. We created a lesion in the food groove and used time lapse recording to reveal the behavior of the food grove post-incision and tentilla growth path. Based on the histology and TEM, we acquired the scheme of cross section of tentacular bulb with the prediction of function in multiple area of bulb. We also found spontaneous slow trains of robust biphasic action potentials in tentilla where they arise from the aboral end of the tentacular bulb of adult animals.

S9-10 DOONAN, L.B. *; HARTIGAN, A; GACESA, R; OKAMURA, B; MARQUES, A.C.; LONG, P.F.; Kings College London, UK , Natural History Museum London, UK , University Medical Center Groningen, The Netherlands, Universidade de São Paulo, Brasil; *liam.doonan@kcl.ac.uk*

Feeling Stressed? The Evolution of Nrf2 Coordinated Oxidative Stress Response in Free-living and Parasitic Cnidarians.

Co-adapted cellular processes that overcame metabolic toxicity resulting from use of highly reactive molecular oxygen, a challenge exacerbated by electrophilic xenobiotics and abiotic agents such as UVR, are crucial to the success of aerobic life on Earth. Oxidative stress is the product of damage to molecules such as proteins, lipids, and nucleic acids caused by reactive oxygen species (ROS). To survive this stressful environment, long-lived species utilize a variety of antioxidant compounds and have evolved many enzymes that inactivate ROS. The expression of enzymes to protect against ROS is coordinated by a small number of related nuclear transcription factors, the most important of these being the master regulator, Nrf2. Regulation of Nrf2 is thought to be largely driven by Keap1. Upon exposure to ROS, Nrf2 dissociates from Keap1 and is shuttled to the nucleus where it activates its target genes. Keap1-Nrf2 interaction is conserved in Drosophila and vertebrates but little is known about this system in early branching metazoans. Using genomic, transcriptomic and proteomic data, we analyzed Keap1/Nrf2 orthologs in several cnidarian taxa as well as other early-diverging metazoans. We also examine other associated oxidative stress response proteins in both parasitic and free-living cnidarians, which may experience different levels of metabolic and environmental toxicity due to diverse life-histories. Investigation of Nrf2 regulation of oxidative stress in basal lineages may advance human medical intervention as well as our understanding of metazoan evolution.

100-5 DORGAN, KM*; LOCKRIDGE, G; BALLENTINE, W; KISKADDON, E; CLEMO, WC; Dauphin Island Sea Lab; *kdorgan@disl.org*

Mechanical properties of muds: a worm's perspective

Muddy marine sediments are elastic materials through which worms extend burrows by fracture. Elastic fracture depends on two sediment material properties: fracture toughness and stiffness. Variability in the ratio of these properties has been shown to affect the behavior of burrowing worms. Very little data exists, however, on how these properties vary in the natural environment. We have identified several problems with previous methods of measuring sediment fracture toughness and have developed and tested an instrument that addresses these problems. We will present data on fracture toughness profiles across a gradient of muddy sediments and will compare fracture toughness to more commonly used geological measurements such as grain size and organic content. Quantifying these material properties of sediments is critical to understanding how burrowing kinematics and mechanics vary in the natural environment. These measurements are also an important step in linking animal-sediment interactions to broader ecological processes in sediments.

P2-279 DOURA, N. M*; CHANDLER, C.; Suny Oswego ; *ndoura@oswego.edu*

Sexually Dimorphic Gene Expression in Terrestrial Isopods

SEXUALLY DIMORPHIC GENE EXPRESSION IN TERRESTRIAL ISOPODS Nora Doura, Christopher Chandler Department of Biological Sciences 392 Shineman Center SUNY Oswego 30 Centennial Dr. Oswego, NY 13126 Males and females of many species differ in characteristics like size or color, and these characteristics may be adaptive. These differences are often the result of different genes being expressed from the genome. Many species of terrestrial isopods show sexual dimorphism, but can also undergo sex reversal because of infection by Wolbachia or experimental manipulations in the lab, making them an interesting system to study the genetic basis of sexual dimorphism. In this study, genes showing sexually dimorphic expression are identified in two species of terrestrial isopods, Trachelipus rathkei and Porcellio laevis. This study will help identify the genetic underpinnings of sexual dimorphism in these species and will help inform future studies on how Wolbachia affects sexual phenotypes. Studying the effects of Wolbachia on gene expression can also lead to further experimentation involving the loss or gain of certain characteristics in the terrestrial species.

63-7 DOW, EG*; RODRIGUEZ-LANETTY, M; Florida Intl. Univ., Miami ; *edow002@fiu.edu*

Cnidarian chemosensory iGluRs under the clout of circadian rhythm in the sea anemone Exaiptasia pallida

Ionotropic glutamate receptors (iGluRs) are a group of transmembrane proteins involved in many biological processes, from chemically mediated neuron communication within vertebrate brains to chemosensation within insect antennae. The group of early-diverged cnidarians includes the sea anemone *Exaiptasia pallida* that contains an expanded diversity of genes throughout iGluR evolution and function as chemosensory receptor proteins capable of response to bacteria. An *E. pallida* iGluR gene has shown cyclic gene expression profiles, prompting the hypothesis that rhythmicity of chemosensory genes may be circadian. To address this hypothesis, we explored whether *E. pallida* iGluR2 expression is dependent on circadian rhythm or has a natural cycle with varied expression through diurnal experimentation. Prior results showed 48 hour cyclical gene expression of *E. pallida* iGluR2, hypothetically stemming from circadian rhythm, shown to influence cnidarian transcription including genes involved in glutamate metabolism. Five biological replicates were sampled randomly over 4 weeks during a 24-hr time period at four hour intervals to compare the expression of EpaliGluR2 between 12-hr light:12-hr dark and 12-hr dark:12-hr dark diurnal cycles. While EpaliGluR2 has conserved domains indicative of homology to the iGluR family, nucleotide substitutions in key conserved residues suggest these diverse iGluR isoforms possess differential specificities and consequently distinct functional roles, putatively in response to light. This study is the first to measure iGluR expression as a function of diurnal influence or circadian rhythm in cnidarians.

S6-1 DOWLING, DK; Monash University; *damian.dowling@monash.edu*

Maternal inheritance of mitochondria, and implications for male health

Maternal transmission of mitochondria renders the mtDNA sequence prone to the accumulation of mutations that are deleterious to male, but not female, function. In this talk, I will describe the evolutionary logic underlying this hypothesis, which is generally known as "Mother's Curse", and provide an overview of its key predictions. I will then present case studies of empirical support for the Mother's Curse hypothesis, which come from my group's research on fruit flies (Drosophila melanogaster), and I will highlight emerging evidence from other model organisms, and humans. Finally, I will discuss the implications and caveats of the current evidence base, and outline future research avenues required to clarify the pervasiveness of "Mother's Curse" mutations in metazoans.

P3-34 DOWNS, AM*; KOLPAS, A; BLOCK, BA; FISH, FE; West Chester Univ., Stanford Univ.; *ad846650@wcupa.edu*

Turning Performance by Bluefin Tuna: Novel Mechanism for Rapid Maneuvers with a Rigid Body

Tunas are considered to be energetic swimmers that are capable of exceptional migrations across ocean basins. Their aquatic performance is due to the thunniform, lift-based propulsion, stiff fusiform body shape, and large muscle mass. Rigid bodies present a limitation to the turning performance of aquatic organisms. To examine turning capabilities in a captive setting, Pacific bluefin tuna (*Thunnus orientalis*) were video recorded from a dorsal view as the tuna routinely swam around a large tank or when being fed. Three different types of turning behaviors were observed. Tuna would glide through the turn using the caudal fin as a rudder. Tuna would continually power through the turn using symmetrical strokes of the caudal fin. Lastly, the tuna used a ratchet turn where the global turn was accomplished by a sequence of rapid, short turns by asymmetrical strokes of the tail. Each short turn rotated the tuna about its center of mass changing the trajectory of the rigid-bodied tuna to collectively turn the fish. The angular velocity of the ratcheting action was over 2.7 times that of the global turn. This previously undescribed maneuver provides a mechanism to turn rigid-bodied aquatic organisms and underwater vehicles.

P3-63 DRAMM, CL*; ORSBON, CP; VARGEESE, JJ; ROSS, CF; GIDMARK, NJ; Knox College, University of Chicago; *cdramm@knox.edu*

The impact of gape on biting force of the masseter muscle in male and female macaque monkeys.

The force-length relationship of skeletal muscle constrains the relationship between biting force and gape in jaw systems. If muscle forces and bite force are highest at minimum gape (occlusion), then forces should decrease at larger gape angles, as the mouth is opened. Male macaques have wider maximum gapes than female macaques to provide clearance to their longer canines, but how that impacts jaw muscle force production is unknown. Here, we present data on the impact of masseter muscle force-length relationships on biting force in male (N = 3) and female (N = 2) Rhesus Macaque (*Macaca mulatta*) monkeys. We electrically stimulated the masseter muscle bilaterally at the full range of possible gapes while measuring bite force at the incisors with a force transducer. Surgically implanted markers in the cranium, mandible, and masseter muscle, combined with X-ray videos allowed the use of XROMM to reconstruct 3D jaw/skull position. Both males and females in our study utilized the ascending, plateau, and descending limbs of the force-length curve, and did not differ significantly in the gape angle that correlates with optimal muscle force. The males' jaws could be depressed to a wider gape angle and distance than the females' and their masseters utilized a greater portion of the descending (= long) end of the force-length curve. Male macaques have larger canines than females, creating a difference in the relationship of muscle length with gape, depending on how gape is measured - i.e., from incisors versus canines. The correlation of canine gape with biting force is nearly identical across both sexes (which is not true of incisor gape), suggesting that macaque jaw musculoskeletal biomechanics are more aligned to canine gape than molar gape, incisor gape, or gape angle.

P1-81 DRAUD, TE*; CHAPPLE, TK; HAHN, TP; WIKELSKI, M; CORNELIUS, JM; Eastern Michigan University, Stanford University, UC Davis, Max Planck Institute; *tdraud@emich.edu*

Impact of severe winter conditions and reproductive status on heart rate in the opportunistically breeding red crossbill, Loxia curvirostra

Energy is the currency of life, where a surplus allows for survival and reproduction and a long-standing debt leads to sickness or death. Real-time monitoring of energy expenditures in free-living animals has been relatively limited by available technology. Continuous tone radio transmitters that have been specially modified to detect heart rate, however, allow for real-time estimation of energy expense in free-living, behaving animals, as well as for close monitoring of behavior. Red crossbills live at northern latitudes and/or high elevations year-round and can breed opportunistically throughout much of the year. They therefore offer a unique opportunity to examine the eco-physiology of different life cycle stages under drastically variable seasonal conditions. Here we present heart rate data from free-living breeding and non-breeding red crossbills in the summer and winter. We discuss these variables in the context of red crossbills' unique opportunistic and nomadic annual schedules and the highly seasonal conditions of our field site in Grand Teton National Park.

99-1 DRAUD, S.L.*; DEAROLF, J.L.; Hendrix College, Conway, AR; *draudss@hendrix.edu*

Fiber-type profile of Atlantic spotted dolphin (Stenella frontalis) diaphragm

Swimming on a breathhold is known to decouple ventilation and locomotion in cetaceans (whales, dolphins, and porpoises). However, the mechanisms underlying this unique behavior are not fully understood. The fiber-type profile of the bottlenose dolphin (*Tursiops truncatus*) diaphragm suggests that this muscle might act as a barrier against the cranial movement of its abdominal organs during flexion of its tailstock, thereby serving as a modulator of the visceral piston. Characterizing the fiber-type profile of the diaphragms of other dolphin species can help us discern if this potential role of the diaphragm is consistent among cetaceans. In this study, we determined the fiber-type profile of six Atlantic spotted dolphin (*Stenella frontalis*) diaphragms. We cut sections using a cryostat, stained them for their myosin ATPase activity after basic pre-incubation, and tested for their reaction to myosin heavy chain antibodies (A4840 - slow myosin; SC71 - fast IIa myosin). The ATPase stained sections were imaged, and the fibers were counted and placed into one of three categories (dark, intermediate, or light). In addition, antibody stains were used to confirm the classification of these fibers as either fast- or slow-twitch fibers, as well as examine the expression of intermediately staining fibers. These data were used to calculate the average fiber-type profile of the diaphragm. Diameters of fibers in each of the three categories were also measured using ImageJ. The fiber-type profile and fiber diameters of the diaphragm of Atlantic spotted dolphins will be compared to these features of the bottlenose dolphin muscle in order to identify any similarities or differences. These comparisons will enable us to better understand the unique role of cetacean diaphragms in their ventilation.

45-1 DRESCH, J.M.*; GAIEWSKI, M; DREWELL, R.A.; Clark University; *jdresch@clarku.edu*

Improving Evolutionary Algorithms for Parameter Estimation

When working with interdisciplinary approaches in biology, such as mathematically modeling of a complex data set, parameter estimation is a critical step. Although it may seem like a simple decision, choosing the appropriate parameter estimation algorithm can be challenging. Key questions to address include: 1) How noisy is the data and how well can we actually fit it? 2) Should we be looking for a single ‘best' solution or is it possible that there may be multiple solutions that are equally biologically feasible? 3) Is it important that the algorithm runs fast or is our only goal to find the parameter set that results in the best model fit, regardless of how long it takes to find it? In this study, we develop new evolutionary algorithms for parameter estimation, using parameter sensitivity to inform the mutation rates, and compare their performance to existing algorithms. The comparison is done on synthetic data sets of varying quality, created using a mathematical model of transcriptional regulation. We find that our newly developed algorithms outperform existing algorithms on high-quality data sets, while algorithm performance is almost indistinguishable on low-quality data sets. Overall, the results from this study will inform modelers and experimentalists regarding which parameter estimation algorithm they should implement on their specific data set.

23-5 DREWELL, R*; KLONAROS, D; DRESCH, J; Clark University; *rdrewell@clarku.edu*

Deciphering the evolution of regulatory grammar in Drosophila Hox gene enhancers

In Drosophila, the Abdominal-B homeotic (Hox) gene is expressed in a spatially and temporally restricted pattern along the anterior-posterior axis during embryonic development. The transcription pattern is controlled through specific interactions between transcription factors and a network of enhancers in the neighboring intergenic regions. We investigate how the sequence architecture and spacing of transcription factor binding sites mediates the functional activity of the enhancers. Using interdisciplinary approaches including bioinformatics, cell-based molecular genetics and thermodynamic-based mathematical modeling experiments we demonstrate that the transcriptional output of the enhancers relies on a complex grammar of conserved transcription factor binding sites with defined binding affinities.

P2-157 DROLET, J; LE POGAM, A; LOVE, OP; VÉZINA, F*; Université du Québec à Rimouski, University of Windsor; *francois_vezina@uqar.ca*

Very Low Heat Tolerance in an Arctic Cold-Specialized Passerine

The snow bunting (Plectrophenax nivalis) is an Arctic-breeding passerine that experience relatively harsh wintery conditions throughout the year. Although the species is well adapted for these environments, our recent work suggest that the species tolerance to moderate summer heat, especially when actively flying, might be low. Since the Arctic is warming faster than the rest of the globe, it is expected that summer temperatures at the time of chick provisioning might limit the birds' scope for physical activity. Heat stress could therefore affect individual performance and reproductive success. Working at the northern edge of their breeding range (Alert, 82°N, Nunavut), we aimed at determining the limits of thermal tolerance in snow buntings and predicting the ambient temperature at which sustained locomotor activity (e.g. flight or chick provisioning) could lead to hyperthermia in chick-rearing birds. This required field measurements of basal metabolic rate (BMR), maximal thermogenic capacity (Msum) as well as minimal and maximal conductance (Cmin and Cmax). Our results show that inactive snow buntings have a surprisingly high heat tolerance (ambient temperature of 36°C) and a high cold tolerance (< -90°C) in standardized conditions. However, our data also show that for a sustainable activity level representative of the chicks provisioning period (4 X BMR), the additive effect of heat and activity could push the birds above their heat tolerance limit at a much lower temperature (12°C in summer), potentially forcing them to reduce provisioning efforts. Since buntings already experience this temperature during the Arctic summer, our data suggest that the species might be very limited in its capacity to cope with the predicted increase in Arctic temperatures in the nearby future.

S12-4 DROTLEF, DM; DAYAN, CB; SITTI, M*; Max Planck Institute for Intelligent Systems; *sitti@is.mpg.de*

Gecko-inspired composite microfibers for reversible adhesion on smooth and rough surfaces

Nature offers inspiring strategies for strong and reversible adhesion in complex environments. For instance, geckos can adhere to rough surfaces with their adhesive pads covered by dense arrays of fine hairs. For the past decade, gecko-inspired micro/nanofibrillar adhesives have been extensively studied and principles of enhanced adhesion by contact splitting, equal load sharing or the mechanism of directional adhesion are well understood. Although artificial mimics demonstrate strong and reversible adhesion and even surpass the performance of the gecko on smooth surfaces, their adhesion on slightly rough surfaces is poor. Recently, alternative approaches inspired by animals´ seta with graded modulus, microfibers with soft tips and hard fibers, adhesive composite materials, and viscous systems directly crosslinked on rough surfaces have been demonstrated. However, their adhesion performance on rough surfaces are still questionable and not very reversible. In this study, we propose gecko-inspired composite microfibers with superior conformation and adhesion to smooth and rough surfaces. The adhesive patterns are composed of polydimethylsiloxane microfibers decorated with very soft and conformal composite mushroom-shaped tips. Tailoring tip geometry, layer thickness, tip composition, together with optimized processing parameters resulting in great surface conformation and enhanced performance. High adhesion strength of more than 200 kPa on smooth and 40 kPa on rough surfaces with high durability was achieved. The proposed composite microfibers enable the implementation of bioinspired patterns to various real world applications, inaccessible for current microstructured systems

P2-232 DROWN, R. M.*; ANDERSON, C. V.; University of South Dakota, Vermillion; *rachel.drown@coyotes.usd.edu*

The functional basis for variable antipredator behavioral strategies in Chamaeleo calyptratus

Selective pressures such as predation, resource availability, and disease influence all animals. To counterbalance these often conflicting demands, many species possess unique morphological, physiological, and behavioral adaptations that increase survival in their environment. Predation, an ever-present selection pressure, is well-suited for studying the relationship between behavior, morphology, and physiology, as the effectiveness of antipredator behaviors may vary depending on a variety of environmental and functional characteristics. Chameleons are a particularly adept model to study the relationship between these adaptations as previous work suggests that antipredator strategies vary significantly with body size and habitat type. Further, their unique morphological and physiological traits, which have adapted in response to their largely arboreal lifestyle, produce relatively slow locomotion, which is poorly suited for fleeing. While fleeing is still a viable strategy, chameleons may also undergo cryptic color changes or behave aggressively to avoid predation. We have examined the functional basis for variation in antipredator behavioral decisions in veiled chameleons (*Chamaeleo calyptratus*) of three different size classes. To do so, we categorized observed antipredator behaviors during mock predation trials and then quantified the performance capacities underlying each potential strategy (e.g., sprint speed and acceleration for fleeing, degree of color change for crypsis, and bite force for aggression) in every individual. Our results indicate that individual differences in performance capacities underlying each behavior influence which response is performed during mock predation trials. The relevance of functional capacities in behavioral decisions provides further insight into the relationship between behavior, environment, and physiology.

79-1 DU CLOS, KT*; LANG, A; DEVEY, S; MOTTA, PJ; HABEGGER, ML; GEMMELL, BJ; University of South Florida, University of Alabama, Florida Southern College; *duclos@usf.edu*

Flexible scales of the mako shark respond to drag inducing small-scale flow features

The shortfin mako shark *Isurus oxyrinchus* is a fast swimming ocean predator that preys on some of the fastest swimmers in the ocean. The mako's fast swimming speeds and its ability to migrate over distances up to thousands of kilometers suggest that drag reduction is crucial for this species. Mako skin is embedded with a layer of often flexibly attached, toothlike scales. Past studies have attributed drag reducing effects of shark skin to the presence of scale ridges oriented parallel to the swimming direction. More recent studies have examined the drag reduction role of scale bristling in which scales move rapidly up and down, which may reduce backflow in reversing, turbulent boundary layer flows. Scale bristling is difficult to observe, however, due to the small spatial and short temporal scales involved. We used ultra high-speed video (50,400 frames per second) to record turbulent boundary layer flow over mako skin from the flank region of the body, a region of high flow separation and the region where scales are most flexible. We recorded videos of mako scales bristling rapidly up and down over approximately two milliseconds. Scale bristling occurred under flow conditions representative of cruise swimming and were associated with two flow features. The first was a downward and backward (toward the anterior of the shark) flow associated with flow reversal that pushed up the scale. The second was an eddy just anterior to the scale that produced a low pressure region that pulled up the scale. This study was the first to directly observe flow induced scale bristling.

74-5 DUELL, ME*; HARRISON, JF; University of Western Ontario, Arizona State University; *duellmeghane@gmail.com*

The pros & cons of small size: Size-dependent flight metabolic rates and thermal performance among stingless bees

Flight can be extremely energetically expensive for many invertebrate ectotherms. Little data on very small flying insects exists to verify how flight metabolic costs change with decreasing body mass. Current estimates are based mostly on measurements from larger insects. We studied the scaling of metabolic rate (FMR) among 13 species of stingless bees, ranging from 1-115mg in body mass, using flow-through respirometry at a fixed temperature of 25°C. We found that an FMR scaling exponent of 2.2, indicating that smaller bee species expend less energy in flight than expected for their size. We measured wing area and veination, head, thorax, and abdomen mass, load carrying, and wing beat frequency (WBF) to explain our results. We found that WBF did not scale with body mass. Load carrying scaled isometrically. Smaller stingless bee species had relatively larger heads. Smaller species had relatively larger wings with less veination. When compared to FMR for all flying insects, we found a breakpoint in the scaling relationship at 53mg body mass. Below this, FMR scaled with and exponent of 1.2 while it scaled with an exponent of 0.67 above, suggesting that smaller flying insects have mechanisms which decrease the costs of flight. We determined that flight temperature did not contribute to FMR by measuring Q_{10} for each species between 25-35°C. Q_{10} was approximately 1 over this range. Thermal performance curves varied by species; flight metabolic rate increased or decreased with increasing air temperatures in some species. In others, there was no effect of air temperature between 25-40°C. However, smaller species had lower flight CT_{max} than larger species, and therefore may be less tolerant of rising air temperatures.

P1-171 DUGGAN, BS*; GEORGE, EM; ROSVALL, KA; Indiana University, Bloomington; *bendugga@iu.edu*

A low-cost, open-source system to wirelessly collect and manage RFID data

Cost-effective radio frequency identification (RFID) technology allows biologists to track the movement of tagged animals using short range antennas. Current reader designs generally record data to memory cards, to be manually uploaded and analyzed on a computer. While this approach may be sufficient for some projects, it does not lend itself to the deployment of large numbers of readers over large geographical areas, without significant logistical drawbacks. Here, we have created a system that wirelessly collects data from readers, stores data on a central server, and transmits data over a locally-generated Wi-Fi network to allow for real-time viewing and basic analysis on a computer or mobile device. This system uses a Raspberry Pi mini-computer, an Arduino board, and a transceiver radio module on every device in the RFID network. We will present the results of simulated and real-world tests of this system to validate radio range, ensure reliability of data transfer, and measure effects on battery life. Furthermore, we elaborate on additional features, such as networking radios together to increase range and integrating mobile hotspots to allow remote data access. This system can facilitate new, ambitious experiments that further extend the scope of behavioral questions that can be answered using RFID technology.

P3-72 DULSKIY, AB*; ORSELLI, K; VON DASSOW, G; College of the Holy Cross, California State University, Northridge, Oregon Institute of Marine Biology; *abduls19@g.holycross.edu*

Effect of Simulated Egg Size Reduction on Larval Performance in Dendraster excentricus

Echinoderm eggs vary in volume over several orders of magnitude, but most that develop into planktotrophic larvae cluster in the nanoliter range (0.3-4 nl). Egg size is an important aspect of maternal investment, and the correlation with developmental mode implies an influence of egg size on developmental mechanisms and larval performance. From the starting material provided by the egg, planktotrophic larvae must build certain essential structures to survive to metamorphosis. These include the ciliary band, which is the primary larval feeding and swimming organ; an alimentary tract; and, for echinoids and ophiuroids, a larval skeleton. We therefore wondered whether scaling constraints preclude echinoderms from making even smaller eggs, and hence more propagules. We simulated egg size reduction in the sand dollar *Dendraster excentricus*, which has an egg size (1 nl) that is nearly modal for obligately planktotrophic echinoids, and observed the effect on larval development. To create half- and quarter-sized "eggs," we separated blastomeres at the two- and four-cell stages. It is well known that echinoid larvae can "regulate", creating complete larvae from each of four blastomeres, but we asked: can these partial larvae effectively move water and capture particles? Can they successfully reach metamorphosis? Do essential structures like the ciliary band scale locally, or with overall embryo size? All three sizes - full, half, and quarter - were able to move water and capture particles successfully, and we successfully raised all three sizes of larvae to metamorphosis, although quarters suffered a substantial burden of defects and asymmetry. We found that the proportion of cells in the ciliary band and the number of nerve cells along the band appears to scale with embryo size. This suggests that although developmental regulation might guarantee partial larvae a complete anatomy, further reduction might erode essential body organs to the point of disfunction, thereby conferring a constraint on egg size.

105-2 DUMAN, AJ*; AZIZI, E; Univ. of California, Irvine; *aduman@uci.edu*

Substrate Stiffness Affects the Coordinated Landing of Rhinella marina

The musculoskeletal system is responsible for safely dissipating energy associated with locomotion. Rapid decelerations of the body and dissipation of mechanical energy are common across modes of terrestrial locomotion including running downhill and landing from a jump. The variation in mechanical properties of the environment can change the rate and magnitude of energy that needs to be dissipated by the musculoskeletal system and may require changes to strategies used to minimize the risk of injury. In particular, the compliance of a substrate may be used to temporarily store energy to reduce the energy imparted on the body upon impact. The well-documented, coordinated landing of *Rhinella marina* offers a unique model to determine how substrate stiffness may influence their landing behavior. Using force-plate ergometry and high-speed videography we compare the landing performance of *R. marina* (n = 5) across four compliance treatments relative to body weight (BW); 0, 2.5, 5 and 10 mm BW^{-1}. Landing performance was characterized by finding the energy dissipated by the forelimbs normalized to the total energy of the system. Inverse Dynamics were also employed to compare the relative energy contributions of forelimb joints as well as how they differ with substrate stiffness. Our results imply that substrate stiffness increases the relative amount of energy dissipated by the forelimbs to decelerate the body.

P2-89 DUNCAN, CM*; CHRISTIAN, HC; CHMURA, HE; BUCK, CL; BRIAN, BM; LOUDON, ASI; WILLIAMS, CT; Univ. of Alaska Fairbanks, Univ. of Oxford, Northern Arizona Univ., Univ. of Manchester; *cmduncan3@alaska.edu*

Ultrastructural Changes Within the Pituitary Associated with Reproductive Timing in a Hibernating Mammal

Reproductive timing strongly influences the fitness of the individual. While most vertebrates rely on photoperiodic changes to induce seasonal puberty, the arctic ground squirrel (AGS) naturally undergoes reproductive maturation in a photoperiod-independent manner. In addition, males spontaneously activate their reproductive axis during hibernation, but the timing of puberty is sensitive to external cues. We are using electron microscopy to examine, define, and measure ultrastructural remodeling in pars tuberalis (PT) thyrotroph cells and anterior pituitary (AP) gonadotroph cells, as the AGS transitions from hibernation to the reproductive season. We are also quantifying how the morphology of endocrine cells corresponds with measures of reproductive axis outputs, including changes in steroidogenic gene expression in gonads and plasma sex steroid concentrations. Finally, we are examining the mechanisms that underly plasticity in hibernation phenology and examining whether AP activity can become dissociated from the PT signaling pathway by assessing cellular remodeling in males placed in a 30°C room during mid-hibernation, which induced early puberty onset. We hypothesize that changes in PT morphology underlie initiation of puberty and the timing of the end of hibernation in a photoperiod-independent manner. This basic system-level investigation of reproductive control mechanisms in the AGS could provide insight into non-photic mechanisms that induce puberty onset and underlie plasticity in pubertal timing.

P3-119 DUNCHEON, E/J*; MCCRARY, M/B; O'KEEFE, J/M; CHAMPAGNE, A/M; Univ. of Southern Indiana, Indiana State Univ.; *ejduncheon@eagles.usi.edu*

Lipid Composition in Bat Skin Reflects the Demands of Flight

Flight in vertebrates places physical stress on many areas of the body, including the skin. The stratum corneum (SC) comprises the outermost 10-20 µm of the skin, and is composed of corneocytes embedded in a matrix of lipids, which contribute to the hydration and strength of the SC. Among mammals, bats have a unique SC lipid composition that includes cerebrosides, ceramides with a sugar moiety attached to the headgroup. Cerebrosides interact with water more strongly than other lipid molecules in the SC, and thus may play a large role in hydrating the SC. Furthermore, cerebrosides are prominent in avian SC, suggesting convergent evolution in SC lipid composition between birds and bats to provide the skin with the necessary moisture and strength for flight. We use thin layer chromatography to quantify lipid composition in four regions of the SC in the big brown bat (*Eptesicus fuscus*). In each region, we identified cholesterol esters, free fatty acids, cholesterol, ceramides, and cerebrosides, representing a more complex lipid composition than other mammals. Additionally, we correlate lipid composition with the stress each skin region experiences during flight. Our results indicate that the lipid composition of bat SC reflects their unique lifestyle.

128-4 DUNHAM, NT*; MCNAMARA, A; HIERONYMUS, TL; SHAPIRO, L; YOUNG, JW; NEOMED, University of Texas at Austin; *ndunham@neomed.edu*

Locomotor kinematics of free-ranging primates in response to changes in substrate diameter and orientation

Primates' near exclusive use of diagonal sequence gaits has been hypothesized to enhance stability on arboreal substrates. To assess how primate gait kinematics vary in complex arboreal environments, we filmed eight species of free-ranging primates (*Ateles*, *Lagothrix*, *Alouatta*, *Pithecia*, *Callicebus*, *Saimiri*, *Saguinus*, and *Cebuella*) at the Tiputini Biodiversity Station, Ecuador, and quantified the diameter and orientation of locomotor substrates using remote sensors (n = 858 strides). Five of the species used primarily diagonal sequence, diagonal couplet (DSDC) gaits. *Callicebus* frequently used lateral sequence gaits (i.e., ~50% of strides). *Saguinus* and *Cebuella* most frequently used asymmetrical gaits. We examined the effects of substrate diameter and orientation on duty factor and interlimb phasing, controlling for speed via ANCOVA. *Ateles* increased limb phase on inclines (p=0.04), *Lagothrix* had greater duty factors on inclines (p=0.002), *Callicebus* exhibited greater duty factors (p=0.04) and lower limb phase values on declines (p=0.001), and both *Saimiri* and *Saguinus* displayed an inverse relationship between limb phase and substrate diameter (p=0.05, p=0.03, respectively). This study confirms the ubiquity of diagonal sequence gaits in free-ranging primates and at least partially supports predicted biomechanical adjustments to promote stability including: increased duty factor on nonhorizontal substrates, increased limb phase on inclines, and decreased limb phase on declines. Other species-specific kinematic adjustments to substrate variation are likely related to body size and ecological variation but require further investigation. Supported by NSF BCS-1640552 and BCS-1640453.

P1-74 DUNN, PO*; HENSCHEN, AE; WHITTINGHAM, LA; Univ of Wisconsin-Milwaukee; *pdunn@uwm.edu*

Gene expression in a sexually selected plumage ornament

One of the grand challenges in animal biology is to understand the influence of genes on the development of phenotypic traits. The plumage of birds encompasses a spectacular array of ornaments long appreciated for their beauty, yet we know little about how the color of plumage patches is influenced by genes. In this study we constructed a de novo transcriptome to examine gene expression in developing feathers of a warbler, the common yellowthroat (*Geothlypis trichas*). This warbler is one of a few species of birds in which a plumage trait, the size of the black facial mask, is known to be sexually selected through female choice. Preliminary analyses indicate that genes related to immunity and oxidative stress (among others) are differentially expressed in the mask of males, compared with feathers from areas of the plumage that are not sexually selected.

52-2 DUNOYER, L/A*; DAPORE, Z; SEIFERT, A; VAN CLEVE, J; Univ. of Kentucky; *ladu225@uky.edu*

Effects of Limb Loss via Autotomy and Regeneration on Reproductive Success in Female Red Swamp Crayfish

Crayfish are keystone species and impact the freshwater stream environment around themselves through ecosystem engineering. Like other arthropods, they are also capable of regeneration after limb autotomy following a predator attack or a competitive interaction. Nonetheless, little is known about the impacts of this regenerative process on the fitness of these ecologically integral organisms. Here, we ask how regeneration following limb autotomy influences egg production as a measure of juvenile and adult fitness. In the lab, we induced autotomy of one cheliped and then mated and isolated female adult and juvenile crayfishes until egg production. Then, eggs were counted and sized as a measure of female fitness. We found no effect of autotomy and regeneration on adult egg production. However, juvenile egg production was negatively impacted. This difference indicates the existence of an allocation trade-off between sexual organs development and regeneration until maturity. Understanding this tradeoff is an essential step toward developing a better understanding of the evolutionary origins of such complex phenotypes as autotomy and regeneration.

1-4 DUQUE, FG*; RODRIGUEZ-SALTOS, CA; MONTEROS, MF; WILCZYNSKI, W; Georgia State Univ., Emory Univ., Univ. Tecnica del Norte; *fduque1@student.gsu.edu*

Signal transmission of high-frequency vocalizations of Andean hummingbirds.

When producing a signal, a sender faces environmental challenges that affect transmission and may prevent the intended receiver from detecting the signal. Therefore, animals produce signals that are adapted to habitat conditions, facilitating intraspecific communication. We assessed signal transmission of high-frequency vocalizations (8-15 kHz) from three species of Andean hummingbirds. *Adelomyia melanogenys* and *Boissonneaua flavescens*, which live in the cloud forest, produce simple high-frequency calls. In high-altitude grasslands, *Oreotrochilus chimborazo* produces longer, more complex high-frequency vocalizations. Playback recordings were collected at 1, 5, 10, 20, and 40 m from the speaker to measure signal attenuation and spectral degradation. Compared to *O. chimborazo*, calls of *B. flavescens* and *A. melanogenys* showed the highest sound levels at 1 m in both habitats, although slightly higher in the cloud forest than in the grasslands. *O. chimborazo* vocalizations were better transmitted at 1 m in their native grassland than in the cloud forest. This shows that each high-frequency vocalization transmits better in its habitat, at least at 1 m. At 5 m, vocalizations of all three species underwent substantial attenuation in both habitats, and they had comparable sound levels. At 20 m, amplitude in all calls was almost indistinguishable from background noise. At this distance, however, spectral fidelity was higher in the grasslands than in the cloud forest for vocalizations of the three species, confirming that high frequencies degrade less in open habitats. Altogether, these results suggest that high-frequency vocalizations in these hummingbirds may be employed in short-range communication rather than in long-distance signaling.

S10-10 DURANT, Sarah; Univ of Arkansas; *sedurant@uark.edu*
Parental incubation behavior is a key link between environmental conditions and avian phenotype
Variation in average nest temperature exists within avian populations. In both altricial and precocial species, these differences in temperature have significant implications for secondary sex ratios of hatchlings and hatchling phenotypes, including traits as varied as hormonal responses to stress and locomotor performance. Climatic conditions and natural and anthropogenic disturbances have the potential to shift incubation behavior of parents, which can alter the nest environment for developing embryos. This talk explores the phenotypic consequences of temperatures experienced during development, factors affecting incubation behavior, and species specific incubation patterns in relation to ambient temperature.

127-2 DURIEUX, DM*; DU CLOS, KT ; GEMMELL, BJ; University of South Florida; *davidduriex@mail.usf.edu*
Aggregation and Benthic Locomotion in Upside-down Jellyfish: Impacts on Feeding and Defense
While most jellyfish are planktonic organisms as adults, actively swimming through the water column, the genus *Cassiopea* is primarily epibenthic, resting with its bell on the bottom and its feeding structures up into the water column. Therefore, bell contractions are rarely used for swimming in open water. In this study, we demonstrate via in situ and in vitro time-lapse imaging of *Cassiopea* from the Florida Keys that these animals exhibit a benthic crawling-type of movement and, using this behavior, organize into chains of individuals instead of clumping or dispersing. The mechanism for this movement is an asymmetrical lateral paddling of the bell margin. While normal swimming utilizes a symmetrical contraction of the bell towards the center of the animal, crawling involves both sides of the bell margin pushing to one side of the animal. Particle Image Velocimetry (PIV) is used to explore the potential for water flow interactions of different spatial arrangements of *Cassiopea*, while quantification of stinging nematocysts released into the water column when *Cassiopea* are disturbed allows for examination of the potential for defensive benefits of aggregation.

138-8 DURSTON, N/E*; WINDSOR, S/P; University of Bristol; *Nick.Durston@bristol.ac.uk*
Quantifying the flight stability of free-gliding birds of prey
Birds adopt a variety of wing and tail configurations during gliding flight, yet it is currently unclear whether these configurations are inherently stable or unstable. Stability influences manoeuvrability and may therefore have a significant impact on behaviours such as foraging, obstacle avoidance and predator evasion. By combining photogrammetric 3D surface reconstructions of a free-gliding barn owl (*Tyto alba*) and peregrine falcon (*Falco peregrinus*) with X-ray computed tomography (CT) scans of similar sized cadavers of the same species, it was possible to accurately estimate the in-flight aerodynamic shape of the birds and their inertial properties. Linear flight dynamics models were then generated using Athena Vortex Lattice (AVL), a computational aerodynamics tool used for aircraft design. The results showed that both the barn owl and peregrine were highly longitudinally statically unstable in glide for all three flights recorded for each species. The peregrine altered its wing and tail configuration with speed and featured varying degrees of camber, twist, sweep and dihedral that resulted in distinct changes to its degree of longitudinal and lateral-directional stability. The dynamic modes showed both similarities and differences with conventional aircraft configurations. Both birds had a stable phugoid and roll-subsidence modes, with a mildly unstable spiral mode. They also had a highly unstable longitudinal mode typical of highly manoeuvrable combat aircraft and similarly would require very fast corrective responses to control. The measured inherent instability of these birds, and the enhanced manoeuvrability conferred, may reflect the need for these predatory birds to catch highly manoeuvrable prey either in the air or on the ground.

P3-147 DZIALO, M*; BRYLA, A; DEMORANVILLE, 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; *maciej.dzialo@doctoral.uj.edu.pl*
Dietary Antioxidants Modulate Metabolism And Organ Sizes In Migratory Birds
Increased oxidative stress associated with avian migratory flights could have a strong impact on energy stores (primarily fats) and in consequence, metabolism during and/or after migration. Migration-related adjustments and the strategies of energy usage could differ between seasons, but may also depend on the different possibilities and limitations of antioxidant capacity in autumn and spring. We used a dietary antioxidant manipulation (AO-low or AO-high) and wind-tunnel flight training over autumn and spring to examine its consequences for basal metabolic rate (BMR) and organ sizes. Female European starlings were flown over a period of 15 days, a total of about 600 km. We found an interactive effect between diet and season that resulted in about ~20% higher BMR in AO-high diet birds in autumn, but with no difference in spring. A similar pattern was observed for the pooled mass of heart and flight muscles (~5% higher in AO-high). Pooled mass of kidney, liver and gut differed only between seasons (~9% lower mass in spring). This indicates that dietary antioxidants can modulate the avian energetics through changes in organs capable to generate a high workload, however, this effect is season-dependent. Improved flight machinery may allow faster migration, but with higher energetic costs. The need for greater energetic reserves upon the arrival at breeding grounds may constrain physiological adjustments during spring migration, although birds may still profit from a high antioxidant capacity and refuel or recover faster after migratory flights. Supported by NSF (IOS-0748349 to S.R.M. and B.J.P.) and NSC Poland (2015/19/B/NZ8/01394 to U.B.)

P3-126 EARLS, KN*; PORTER, MS; RINEHART, JP; GREENLEE, KJ; North Dakota State University, Fargo, ND, Pennsylvania State University, University Park, PA, USDA-ARS, Fargo, ND; *kayla.earls@ndsu.edu*

Effects of Cold Stress on Reproductive Fitness in the alfalfa leafcutting bee, Megachile rotundata

The alfalfa leafcutting bee, *Megachile rotundata*, is an extensively managed solitary bee that may experience low temperature stress during metamorphosis. After diapause, pupae can be exposed to cold stress through spring cold snaps and agricultural practices that postpone development until crop conditions are favorable. Cold stress has been found to cause abnormalities in adult bees. However, the effects of low temperature stress on their reproductive fitness is unknown. The purpose of this study was to test the hypothesis that cold stress reduces fitness. Pupae were exposed to either constant or fluctuating cold stress for one week during metamorphosis, released into an alfalfa field after adult emergence, and compared to bees that were not interrupted. Twenty females and 10 males were released in 9 field tents (6.1m x 6.1m x 2.4m) placed in an alfalfa field and monitored for 3 weeks. Fitness and offspring characteristics were measured by the number of offspring, sex ratio, and diapause incidence. Bees exposed to constant cold stress had fewer offspring compared to controls or bees exposed to fluctuating temperatures. While the fluctuating treatment did not cause a reduction in fitness, offspring were more likely to enter diapause, suggesting mothers interpreted environmental conditions differently. This study is the first to show how field performance, fitness, and offspring characteristics, are affected by a stressor experienced before adult emergence in *M. rotundata*.

12-2 EBERTS, ER*; DICK, MF; WELCH , KC; University of Toronto Scarborough; *ebertser@gmail.com*

No Midnight Snacks for Hummingbirds: Rapid Nighttime Expenditure of Crop-Stored Sugar in Ruby-throated Hummingbirds

During the day, hummingbirds quickly metabolize floral nectar to fuel the high metabolic demands of hovering flight. At night, hummingbirds are unable to forage, and must rely on stored energy reserves to fuel their nocturnal metabolism. Though stored fat is the primary nocturnal metabolic fuel, it has been suggested that hummingbirds store nectar in their crop to offset fat expenditure in beginning of the night, or to directly fuel their first foraging trip in the morning. We examine the use of crop-stored sugar in the nocturnal energy budget of ruby-throated hummingbirds (Archilochus colubris) using respirometry and 13C stable isotope analysis. We predicted that hummingbirds would first exhaust crop-stored sugar, and subsequently metabolize fat stores as the primary fuel until their first feeding the following morning. Hummingbirds were fed a 13C-enriched sugar solution before lights out and held in respirometry chambers overnight without food. Respiratory exchange ratios (RER) and breath stable isotope signatures (δ13C) indicate that the hummingbirds metabolized labeled sugar for less than 2 h and used fat as the fuel for the remainder of the night. Overall, this study provides insight into how hummingbirds can shift fuel usage at night in order to optimize their daily energy budget.

P1-100 EDMONDS, KE; Indiana University Southeast; *kedmonds@ius.edu*

Regulation of Gastrointestinal Development and Reproduction in the Marsh Rice Rat (Oryzomys palustris)

Environmental factors and hormones can regulate the development of various physiological systems. Photoperiod, melatonin, and thyroid status are known to affect significantly the reproductive system in seasonal breeders, but effects on the GI tract have not been as well studied. The present studies examined whether constant light (which inhibits melatonin release), oral melatonin administration, and hypothyroidism affect gastrointestinal (GI) development and reproduction in juvenile male rice rats. Rice rats were subjected, in separate experiments, to 14L:10D or constant light (24L:0D) photoperiods, the administration of oral melatonin, or the administration of oral propylthiouracil (PTU; 0.06%) to induce hypothyroidism from 21-56 days of age. The following masses were examined: body, testes, seminal vesicles (SV), Harderian glands (HG), spleen, and wet (W) and dry (D) masses of the stomach (St), small intestine (SI), cecum (Ce), and colon (Co). In addition, small intestine and colon lengths were measured. Constant light significantly reduced only SV and HG masses; there was no effect on any other variable examined. Oral melatonin administration reduced body, testes, SV, HG, WSt, WCo, DCo masses and the SI and Co lengths. Hypothyroidism reduced masses of the body, testes, SV, and HG, while causing decreases in only the WCe and DCe masses. These data show that melatonin most dramatically affects growth, reproduction, and GI development in males, but that constant light and hypothyroidism were without effect on most GI endpoints. It was hypothesized that changes in the GI tract may be a necessary mechanism for coping with likely seasonal changes in metabolic requirements. We are currently examining the effects of daily food restriction on these same variables in males.

P1-78 EDWARDS, KM*; REZNICK, DN; University of California, Riverside; *kedwa007@ucr.edu*

Specialization for Two Feeding Modes in High and Low Predation Guppies (Poecilia reticulata)

Guppies from the 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 these upstream localities live in communities with far lower risk of predation. This lowered risk allows them to grow to large population sizes with high densities. This high density creates strong competition between individuals for food resources, which forces a diet shift in the population from a preference for invertebrates in high predation communities towards the consumption of more algae and detritus in low predation communities. Guppies are a part of the Cyprinodontiform group, the most basal members of which are generalized suction feeders. The 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 three pairs of high predation and low predation streams from three different Trinidadian drainages to see if differences in diet are associated with differences in jaw and head shape. The dietary shift in the low predation guppies is expected to be accompanied by a shift from the more gracile jaw morphology of a picker towards the more robust and asymmetrical morphology of a scraper. Specimens were cleared and stained, photographed through a microscope from various angles, landmarked and analyzed using canonical variate analysis and discriminant function analysis. Jaw shape was largely influenced by drainage of origin, with low predation populations showing a varied evolutionary response that was consistently significantly different from their high predation counterparts.

97-8 EDWARDS, PD*; BOONSTRA, R; University of Toronto Scarborough; *phoebe.d.edwards@gmail.com*

The Neuroendocrinology of Population Cycles in Voles

Microtine rodents (voles and lemmings) go through marked 3-4 year population cycles throughout the northern hemisphere. The demography of these cycles has been well-documented over decades of research. However, the observation that populations can still go into decline, even when environmental conditions are ideal, has not been explained. Further, there are distinct phenotypes of rodents in the increase and decline phases of the cycle. Thus, there appears to be intrinsic changes in the animals during the peak of the cycle that can limit population growth. We test the hypothesis that high population density, acting through social interactions, induces physiological changes in voles. We experimentally manipulated meadow voles (*Microtus pennsylvanicus*) in field enclosures at low and high population densities, and examined the impact at multiple levels. Expression differences in key regulatory endocrine receptors in the brain will be discussed.

P1-89 EDWARDS, KM*; CAINE, PB; LACEY, LM; HATCH, SA; BENOWITZ-FREDERICKS, Z M; Bucknell Univ., Inst. Seabird Research & Cons.; *kme012@bucknell.edu*

Chick Triglyceride Levels May Reflect Parental Provisioning Decisions in Response to Experimental Food Reduction

Seabirds live in variable environments where food availability is unpredictable and its abundance can fluctuate quickly. During food shortages, parents must balance tradeoffs between their current and future reproductive attempts by adjusting their chick provisioning behavior. Offspring hatching order and sex can influence the costs and benefits of parental investment. We tested the hypothesis that hatching hierarchy and chick sex affect parental provisioning in response to a sudden food reduction. Throughout the breeding season, we supplemented the diets of wild, nesting black-legged kittiwakes (*Rissa tridactyla*) daily. During early chick rearing, we withdrew the food supplementation from some ("withdraw") nests but continued feeding control nests. We weighed chicks immediately before and 3 days after food withdrawal and weighed age-matched control chicks on the same dates. Blood samples were taken concurrent with weighings for quantification of plasma triglycerides, a lipid substrate indicative of avian nutritional state and change in body mass. The effects of food withdrawal primarily manifested themselves in first-hatched (A) chicks, with no significant differences between control and withdraw groups in second-hatched (B) chicks. Overall, withdraw A chicks gained less mass and showed decreases in triglyceride levels, resulting in significantly lower post-withdrawal body masses and plasma triglyceride concentrations compared to controls. Female A chicks exhibited the same pattern, but male A chicks did not. This variation in chick response may reflect either an increased vulnerability of female A chicks to food reduction or a parental decision to preferentially buffer male A chicks from the effects of food shortages.

S1-1 EDWARDS, Erika J*; OGBURN, Mathew R; Yale University; *erika.edwards@yale.edu*

A Green Wave comes to SICB: two days of plant integrative and comparative biology

This symposium is part of an effort to bring greater participation of plant biologists to SICB, and is part of the Special Focus Meeting on Organismal Botany within the Tampa SICB meeting. SICB began in 1902 as the American Society of Zoologists, and has always had a strong taxonomic bias toward animals, despite the name change to the taxonomically inclusive Society for Integrative and Comparative Biology in 1996. This symposium will bring a range of outstanding integrative plant biologists to the annual SICB conference and into membership in the society, resulting in greater cross-pollination of concepts and approaches among integrative biologists regardless of taxonomic focus. The research highlighted in the symposium will demonstrate the diversity of research representing integrative plant biology. The talks will cover topics ranging from scaling and developmental integration to ecological adaptation to evolutionary innovation, and encompass plant taxonomic diversity from seed plants to green algae. This symposium will strengthen SICB's mission to be an organization for all integrative biologists, as well as to put SICB on the map as a natural home for the next generation of emerging leaders in plant organismal and evolutionary biology.

S1-12 EDWARDS, Erika J; Yale University; *erika.edwards@yale.edu*

The distinct evolutionary trajectories of C4 and CAM photosynthesis

Evolutionary convergence provides a special opportunity to dissect the environmental and organismal context surrounding the repeated origins of similar features. Often times, convergence itself is phylogenetically patterned, with certain lineages having evolved particular characteristics multiple times, while other lineages never have. C4 and CAM photosynthesis are two plant adaptations that are remarkably convergent, together evolving hundreds of times, and mostly within the last 10 million years. They stand as exceptional model systems for understanding the repeated evolution of complex phenotypes, and in understanding the phylogenetically clustered nature of this convergence. In this talk I will highlight what we have learned about the evolution of C4 and CAM syndromes, focusing on the increasingly predictable stepwise evolutionary integration of anatomy, biochemistry, and molecular optimization. I propose a general model that explains and unites C4 and CAM evolutionary trajectories, and also highlights some key differences in their dynamics. Available data suggest that in both C4 and CAM evolution, it is the anatomical rather than biochemical modifications that act as the "macroevolutionary bottleneck" in each trajectory. In the case of C4, I'll argue that the anatomical changes precede the assembly of a new biochemical cycle, whereas in CAM the biochemistry is assembled in relatively unspecialized tissue, and the anatomical bottleneck occurs subsequently. Whether this bottleneck occurs early or late in the evolutionary assembly of a new phenotype may have profound implications for the distribution of certain adaptations across the Tree of Life.

S3-3 EDWARDS, J; Williams College; *jedwards@williams.edu*

The Role of Water in Effecting Rapid Movements in Plants

Plants lack muscles, yet can carry out extraordinarily rapid movements in the order of milliseconds or less. Many of these ultra fast movements are mediated by water. Here I compare the rapid movements of three plants: the liverwort, *Marchantia polymorpha*; the moss, *Sphagnum* spp.; and the flowering plant, *Cornus canadensis* (bunchberry dogwood). Each uses specialized morphological features and the movement of water to effect ultra rapid movements, which are used to disperse spores or asexual reproductive propagules. These species illustrate three different ways that water can bring about rapid movement in plants. *Marchantia* directly harnesses the kinetic energy of falling raindrops to propel gemmae (asexual reproductive propagules) from hour-glass shaped gemma cups. For *Sphagnum*, water loss from the capsule walls causes the capsule walls to shrink and build up internal air pressure in the capsule. The result is a sudden explosion that disperses spores in a vortex ring. Finally, the petals and stamens of bunchberry dogwood build up turgor pressure putting both petals and the stamen filaments under tension. Visits by insects release the stored mechanical energy and result in explosive flowering opening and pollen (spore) dispersal from the trebuchet-like stamens.

P3-145 EGAN, JP*; BLOOM, DD; SIMONS, AM; Conservation Sciences Graduate Program, University of Minnesota, Department of Biological Sciences, Western Michigan University, Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota; *eganx149@umn.edu*

Phylogenetic Analysis of Trophic Niche Evolution and Spatial Patterns of Herbivory in Clupeoidei (Herrings, Anchovies, and Allies)

Biotic and abiotic forces govern the evolution of trophic niches, which profoundly impact ecological and evolutionary processes and species biology. Herbivory is an interesting niche because there are theorized trade-offs associated with diets comprised of low quality food that might prevent the evolution of herbivory in certain environments. For this study we investigated trophic niche evolution in Clupeoidei (herrings, anchovies, and allies) and tested the hypotheses that herbivory is negatively correlated with salinity and latitude using a novel, time-calibrated molecular phylogeny, trophic guilds delimited using diet data and cluster analysis, and standard and phylogenetically-informed statistical methods. Phylogenetic comparative analyses did not identify significant negative correlations between latitude and herbivory or salinity and herbivory. In clupeoids there were five evolutionary transitions from non-herbivore to herbivore trophic guilds and no transitions from herbivore to non-herbivore trophic guilds. There were no transitions to zooplanktivore, the most common guild, but it gave rise to all trophic guilds, except algivore, at least once. Transitions to herbivory comprised a significantly greater proportion of trophic guild transitions in tropical/subtropical relative to temperate areas. These findings suggest that cold temperatures may constrain the evolution of herbivory and that herbivory might act as an evolutionary "dead-end" that hinders subsequent trophic diversification and zooplanktivory an evolutionary "cradle" that facilitates trophic diversification.

P3-38 EISINGER, M*; OUFIERO, C; Towson University; *meisin1@students.towson.edu*

Does the Reappearance of a Dorsal Fin in the Black Ghost Knife Fish Apteronotus albifrons Affect Swimming Kinematics?

Apteronotus albifrons, or the gymnotiform black ghost knifefish, is known for its ribbon-like motion of the anal fin during swimming. This anal fin contains approximately 150 individual fin rays that allow for full movement of the fin. While these fish possess an elongate anal fin for locomotion, they completely lack a dorsal fin. However, due to inbreeding or relaxed selection, a mutant strain of A. *albifrons* exhibits an elongate dorsal fin. The presence of the dorsal fin mutation allows for the opportunity to study the effects of the dorsal fin on gymnotiform swimming. This dorsal fin is unique because it does not seem to function like a normal fin; it does not seem that the fish can control the fin. Preliminary internal morphology of the regained dorsal fin suggest that the mutant knifefish regained both the individual fin rays and fin ray supports as seen in the fully functional anal fin. While the swimming kinematics of normal A. *albifrons* have been previously described, the goal of this project was to determine the effect of a regained dorsal fin in the mutant knifefish on routine swimming kinematics and abilities. Using 5 mutant and 4 normal knifefish of similar size, we compared the swimming kinematics of the anal fin (e.g., amplitude and wavelength) during routine forward, backward and hover swimming. Fish were filmed at 250 Hz and fin kinematics were analyzed in ImageJ. Preliminary results suggest that the reappearance of the dorsal fin does not alter routine swimming kinematics. We discuss these results in the context of knifefish locomotion and dorsal fin function.

P3-133 EL SAADI, M; MACMILLAN, HA*; Carleton University; *heath.macmillan@carleton.ca*

Recovery Time, Survival, and Hyperkalemia During Fluctuating Thermal Regimes in Drosophila melanogaster

Insects exposed to low temperatures typically enter a state of paralysis known as chill coma, and individuals that do not die from the cold can recover from this state after an amount of time known as Chill Coma Recovery Time (CCRT). Both low temperature injury and prolonged CCRT have been causally associated with progressive hyperkalemia in the cold. In a Fluctuating Thermal Regime (FTR), warm recovery periods interrupt periods of low temperature exposure and enhance low temperature survival. In this study, we examine whether longer recovery periods improve survival and speed up CCRT of female *D. melanogaster*, and if so, whether this effect can be attributed to superior restoration of K^+ balance during these warm periods. Flies subjected to a single prolonged cold stress, as well as flies that experienced multiple cold exposures with shorter warm periods, had higher mortalities and higher CCRTs than flies that stayed warm for longer between cold bouts. Thus, a FTR with longer warm periods enhances survival and reduces CCRT, but whether this is directly or indirectly a result of an improved ability to restore extracellular K^+ balance during warm periods is unknown. We thus tested this hypothesis by measuring hemolymph K^+ concentrations in female flies under the same conditions.

P1-113 ELDERBROCK, EK*; SMALL, TW; SCHOECH, SJ; College of Wooster, University of Memphis; *eelderbrock@wooster.edu*

Nestling Corticosterone Levels are Increased After Adult Provisioning in Florida Scrub-Jays

Nutritional deficiency often results in increased corticosterone levels in nestling birds and corticosterone, a metabolic and stress-related steroid hormone, is hypothesized to play a role in mediating begging behavior. Further, previous studies have found that corticosterone levels of nestlings are negatively correlated with parental nest attendance and provisioning rates. In this study we examined the relationship between adult provisioning and nestling glucocorticoid levels in a free-living species, the Florida scrub-jay (*Aphelocoma coerulescens*). We monitored parental activity at the nest immediately prior to blood sampling and found that nestling corticosterone levels varied as a function of parental provisioning rate and the time since their last feed. Counter to our predictions, higher provisioning rates and more recent feedings were associated with higher corticosterone levels in nestlings. These results suggest that either the act of feeding by parents, the process of digestion, sibling interactions, or some combination of the preceding resulted in increased baseline corticosterone levels in nestling Florida scrub-jays. These results indicate that some caution should be taken in interpreting elevated nestling baseline corticosterone levels as indicating "nutritional stress" or other distressed states in the absence of knowledge of the individual's recent behavioral history.

74-3 ELIASON, EJ; University of California, Santa Barbara; *erika.eliason@lifesci.ucsb.edu*

Mechanisms underlying sex-specific mortality in Pacific salmon

Thermal tolerance can vary widely across individuals of the same species. For example, our research has shown that thermal tolerance differs across populations, over the life history, and between sexes in Pacific salmon. We take advantage of this variation to look for the underlying mechanisms that determine thermal tolerance. Over the last decade or so, research has shown the adult female Pacific salmon have much higher mortality compared to males, particularly when they are exposed to secondary stressors (e.g. high temperature). Our most recent work has focused on trying to understand the mechanisms underlying this mysterious phenomenon. We examined several hypotheses: 1) Males have higher aerobic scope and swimming performance at elevated temperatures; 2) Females experience cardiac collapse due to reduced oxygen delivery to their hearts; 3) Females have impaired recovery from stressors at high temperature; 4) Females accumulate increased oxidative damage compared to males.

67-3 ELSHAFIE, SJ; Univ. of California, Berkeley; *selshafie@berkeley.edu*

Earliest Evidence of Tail Regeneration in a Derived Fossil Squamate

Caudal autotomy, the ability to shed the tail, is common among lizards as a defense mechanism to escape predation. This trait is a basal synapomorphy of Lepidosauria. About two-thirds of extant lizard families include species that retain the ability. Many can also regenerate the tail as a cartilaginous rod. The oldest known fossil evidence of tail regeneration in a squamate comes from a gekkonid specimen from the Late Jurassic Solnhofen deposits (150 Ma) in Germany. This specimen has a truncated tail and an impression of a rod, visible under UV light, where the tail is missing. No other fossil squamate material showing signs of tail regeneration has been previously described. Here I report the first documented evidence of tail regeneration in a derived fossil squamate, a glyptosaurine (Anguidae) lizard from the early middle Eocene Bridger Formation (49~46 Ma) in the Bridger Basin of southwestern Wyoming. The specimen includes a 1.5-cm segment of the tail with *in situ* imbricate osteoderms. Two rings of larger osteoderms surround the anterior half, and three rows of osteoderms that are 50% smaller surround the posterior half. Autotomized tails in extant anguid lizards also have smaller osteoderms on the regenerated portion of the tail, even when it has regrown to its full length. In the glyptosaurine specimen, the tail diameter past the breakage point is only 65% that of the original half. Extant lizards also exhibit an abrupt decrease in diameter between the original and the regenerating portions of the tail. Computed tomographic scans reveal a caudal vertebra preserved inside the osteoderms, with an intravertebral fracture plane. The scans also reveal a bony callus on the left medial wall of the osteoderms, indicating that the animal sustained an injury or infection as the tail regenerated.

100-1 ELUL, T*; HA, J; LAKHANI, F; BURKE, M; RADHIKA, R; REVELS, J; Touro University California; *tamira.elul@tu.edu*

beta-catenin and Myosin II differentially regulate optic axon pathfinding and growth cone morphology in the optic tract

The retino-tectal projection of lower vertebrates is an experimentally amenable neuronal circuit for studying mechanisms of axon pathfinding in situ. To establish the retino-tectal projection, optic axons must navigate through the optic tract to their target tissue in the midbrain- the optic tectum. Here, we studied how two essential cyto-mechanical factors -beta-catenin and Myosin II - function to regulate optic axon pathfinding and growth cone filopodia in the optic tract of whole brains taken from Xenopus tadpoles. We expressed a mutant of β-catenin that contains the alpha-catenin but lacks the Cadherin binding site (b-catNTERM) in, and applied the Myosin II small molecule inhibitor Blebbistatin to, optic axons in the optic tract of intact brains. Expression of β-catNTERM increased dispersion of optic axons in the dorsal half of the optic tract. In contrast, application of Blebbistatin inhibited extension of optic axons through the optic tract of whole brains. In addition, optic axons that expressed -catNTERM formed growth cones that were bulbous lacked filopodial protrusions, whereas growth cones of optic axons that were exposed to Blebbistatin displayed long, thin filopodial protrusions in situ. These results suggest that β-catenin and Myosin II differentially sculpt optic axonal projections and growth cone filopodial protrusions in the optic tract. More broadly, our findings imply that optic axons may express distinct types of growth cone filopodia that regulate specific axon pathfinding behaviors such as fasciculation and extension in the optic tract.

141-1 EMBERTS, Z*; ST. MARY, CM; FORTHMAN, M; MILLER, CW; University of Florida; *emberts@ufl.edu*

The Evolution of Sacrificing a Limb (i.e., Autotomizing) to Escape Predation

Predation can impose a strong selective pressure. In turn, prey can evolve extraordinary defenses (i.e., anti-predatory traits) that reduce their vulnerability, contributing to the morphological and behavioral diversity we see in animals today. One of the most extreme forms of anti-predatory defense is autotomy, as individuals literally sacrifice part of their body attempting to get away. A lizard dropping its tail to escape predation is an iconic example. However, autotomy also occurs in a diversity of other organisms: octopuses can release their arms, crabs can drop their claws, and bugs can amputate their legs. Still, despite having multiple origins, fundamental questions of how this extreme trait evolves remain unanswered. Most notably, how does a population go from being unable to autotomize, to being able to drop their limbs quickly enough to escape the grasp of a predator? To provide insights into this question, we investigated the evolution of autotomy (latency and ability) in leaf-footed bugs (Hemiptera: Coreoidea) using a macroevolutionary approach.

S1-11 EMERY, NC*; LA ROSA, RJ; University of Colorado Boulder; *Nancy.Emery@Colorado.edu*

Temporal Variation as a Driver of Species' Distribution Patterns

Organisms exhibit diverse strategies for managing changes in their environment: some avoid it by specializing on subset of conditions, others rely on adaptive phenotypic plasticity, and still others maintain a conservative bet-hedging strategy that minimizes variance in fitness over time. Understanding how these different strategies arise, and the circumstances that favor one strategy over another, may be critical to explaining plant distribution patterns and how they will respond to future environmental change. Here, we tested if variation in plant strategies for managing temporal heterogeneity can explain the fine-scale distribution patterns of three co-occurring annual congeners across flood gradients in vernal pool wetlands of California. We quantified variation in traits and fitness for each species under four different hydroperiods and three different levels of variability in a stochastically-fluctuating water table. We found that growing at or below the water table reduced the performance of all species - even those that regularly occupy flooded positions in vernal pools. Furthermore, the species that occupy more hydrologically stable microhabitats were less tolerant of stochasticity in the flooding regime. Finally, the fitness benefits of phenotypic plasticity changed with the degree of stochasticity in the water table, emphasizing that phenotypic plasticity is not advantageous when environmental change is not predictable. These results emphasize that species' adaptations for managing temporal variation can be an important and under-appreciated driver of distribution patterns.

65-2 ENG, CM*; OLIVER, JD; MARSH, RL; AZIZI, E; ROBERTS, TJ; Brown University, University of California, Irvine; *carolyneng@gmail.com*

A new role for intramuscular springs in energy cycling during locomotion

Elastic structures associated with muscle play a key role in energy cycling during cyclical movement. While the role of tendons in energy storage and recovery is well-established, the role of intramuscular connective tissues (IMCTs) is less clear. The arrangement of Hill-type muscle models dictates that length changes in muscle fibers and the elastic elements within muscle are equal. In this model, when muscles undergo isometric contractions in locomotion, IMCTs are not stretched, and therefore cannot store elastic energy. We developed a model with an alternative arrangement to reflect the strains that IMCTs may undergo during deformation of pennate muscles during contraction. In the model, the IMCT is represented as a transverse elastic element (TEE), perpendicular to the muscle's line of action. A component of fiber force compresses the TEE, influencing muscle thickness and pennation angle. To explore the role of a TEE in locomotion, we drove the model with a constant fiber length and sinusoidal force pattern and calculated pennation angle, muscle length, and thickness. Modeling results were tested against *in vivo* biplanar fluoroscopy recordings of locomoting turkeys whose lateral gastrocnemius muscles were implanted with radiopaque beads. Both the model and *in vivo* data showed muscle belly lengthening and shortening, indicating energy cycling. In the model, muscle length changes were accommodated solely by changes in fiber rotation and muscle thickness. Fibers changed length *in vivo*, but energy storage and recovery was also accommodated by changes in muscle thickness, consistent with energy cycling in the thickness direction. Contrary to predictions from Hill-type models, the TEE model suggests that energy cycling in the IMCT is potentially substantial.

P2-226 ENGLER, HI*; ASSIS, BA; OWEN, DAS; LANGKILDE, T; The Pennsylvania State University; *hie1@psu.edu*

Are post-anal scales a secondary sex characteristic in eastern fence lizards?

Secondary sex characteristics differentiate males from females but are not directly involved in reproduction. The sexually dimorphic fence lizard, *Sceloporus undulatus*, has several secondary sex characteristics, such as color badges and body size, which appear in adulthood. In addition, post-anal scales - enlarged scales above where the hemipenes evert from the cloaca - distinguish males (who have these scales) from females (who do not) even at hatching. However, beyond being ubiquitously used as an easy, noninvasive way to sex many species of lizard immediately after hatching, little is known about this sexually-dimorphic trait. We tested for relationships between the size of post-anal scales and both testosterone levels and brightness of throat badge coloration in males from hatching to adulthood. We found that males with larger post-anal scales had higher testosterone levels and brighter throat badges. These results suggest that post-anal scales may function as a secondary sex trait in this and possibly other species. Further research should examine the mechanisms controlling the development and growth of post-anal scales, and their potential function (e.g. possibly in supporting the hemipenis during mating).

63-8 ENRIQUEZ, VL*; CROOK, RJ; ZINK, A; San Francisco St. Univ.; *vivienenriquez93@gmail.com*
Effects ofVibrio fischeri colonization on cognition, foraging behavior, and survival in the Hawaiian bobtail squid
The symbiosis between the Hawaiian bobtail squid (*Euprymna scolopes*) and the bioluminescent, marine bacterium *Vibrio fischeri* has provided groundbreaking insight into the molecular interface of animal host and bacterial symbiont interactions. However, an in-depth analysis of the influence of *V. fischeri* on host behavior remains largely unexplored. While previous research suggests that squid rely on light produced by *V. fischeri* solely as an anti-predatory strategy, it is unknown if the absence of the bacterium affects squids' foraging behavior and overall survivorship. We hypothesized that the exclusion of *Vibrio fischeri* from the Hawaiian bobtail squid's environment negatively affects squid foraging behavior and survival. To test this hypothesis, squid hatchlings were reared in either *V. fischeri* positive or negative environments. Daily behavioral observations were conducted for the first 1-14 days post-hatching, and then on a weekly basis at 21, 28, 35, and 42 days post-hatching. At 8 weeks post-hatching, colonized and uncolonized squid were tested for learning and memory via the "prawn-in-a-tube" assay. To measure survival the number of surviving hatchlings in each treatment between 1-42 days post-hatching were recorded. Preliminary results demonstrate a significant light-level dependent decrease in *Vibrio*-free hatchling survival while foraging and cognitive behavior appeared unaffected. This study will enhance our existing knowledge of the organismal-level effects of the squid/*Vibrio fischeri* symbiosis and provide insight into the diverse ways in which microorganisms play crucial roles in characteristic animal behaviors and survival.

22-5 ENSMINGER, D.C.; The Pennsylvania State University; *dce133@psu.edu*
Effects of maternal glucocorticoids on offspring absolute telomere length in wild lizards.
The effect of maternal glucocorticoids (GCs; stress-relevant hormones) on offspring phenotype is of growing interests to the fields of biology and ecology, particularly during times of increased environmental perturbations. However, little is known about the underlying mechanisms of these alterations or the long-term effects of maternal GCs on offspring lifespan. Telomeres, the protective endcaps of chromosomal DNA, could play a role in both of these effects as telomere shortening is associated with many disease states and cellular senescence. While few studies have explored this in wild animals, many of those studies examine relative telomere length, decreasing our ability to compare telomere length across studies. Here, we use a modified RT-qPCR assay protocol to assess absolute telomere length from small amounts of DNA (<60ng). We tested the hypothesis that increased maternal GCs during pregnancy will decrease offspring telomere length as GCs have been shown to increase reactive oxygen species generation which can decrease telomere length. 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 and hatchlings sampled for DNA. Elevated maternal GCs decreased offspring telomere length of sons but not daughters. These results support the presence of sex specific effects of maternal GCs on offspring telomeres. Further research should explore the fitness consequences of this alteration.

P2-235 ENTZIAN, RP*; EMBERTS, Z; ST. MARY, CM; MILLER, CW; Univ. of Florida; *rentzian@ufl.edu*
Multiple Weapon Morphs in Leaf-Footed Bugs
When sexually selected weapons are polymorphic, it is often the case that one of the morphs has a large weapon, while the other is unarmed. However, recent studies in both harvestman and beetles have found the presence of multiple, distinct, weapon morphs. The maintenance of such variation suggests more complicated alternative mating strategies are at play. Here, we investigated weapon polymorphism in two leaf-footed bug (Insecta: Hemiptera: Coreidae) species. Many species of leaf-footed bugs have enlarged, sexually dimorphic, hind legs, which they use to compete with other males over access to mates and resources. These hind legs come in a diversity of forms, even within species, making them ideal for investigating the presence of weapon polymorphisms. Using linear measurements, we found evidence to suggest the presence of weapon polymorphism in at least one species of leaf-footed bug. Body size was a poor predictor of weapon morph, which suggests that this may be a genetic polymorphism. To our knowledge, this is the first species to show evidence of weapon polymorphism without also recovering an unarmed, minor, morph.

95-6 ENZOR, LA*; MOSO, E; HAMILTON, M; HANKINS, C; RAIMONDO, S; BARRON, MG; U.S. Environmental Protection Agency; *enzor.laura@epa.gov*
Elevated pCO$_2$ and Hypoxia Alter the Acid-Base Balance of Developing Sheepshead Minnow, Cyprinodon variegatus
Estuarine fish are adapted to living in an environment with rapid and frequent changes in temperature, salinity, pH, and dissolved oxygen (D.O.) levels. While the adverse effects of low D.O. on estuarine fish physiology has been well-documented, only recently has elevated pCO$_2$ and the interaction between low D.O. and elevated pCO$_2$ been a research focus area. We explored how the combination of low D.O. (~2 mg/L) and elevated pCO$_2$ (~2000 µatm) altered the acid-base equilibrium of sheepshead minnow, *Cyprinodon variegatus*, as these fish developed from 24-hour old embryo to juvenile fish. We investigated the disruption of cellular homeostasis in these fish using carbonic anhydrase and Na^+/K^+ ATPase enzyme activities, and evaluated the impacts of these stressors on fish development and the costs of restoring acid-base equilibrium. Results from this study will be used to identify to what extent estuarine species acid-base balance is impacted by the interaction of low D.O. and elevated pCO$_2$, and which life-stage may be the most vulnerable to this impact.

P1-71 ERB, AJ*; TURNER, AH; Stony Brook University; *arthur.erb@stonybrook.edu*
Braincase anatomy of the Paleocene crocodyliform Rhabdognathus.
Dyrosaurids, specialized marine relatives of crocodylians, are one of few archosaur lineages to survive the K-Pg extinction and present a unique combination of morphology and ecology absent in living crocodylians. Little is known about their endocranial anatomy, leaving questions about their neurosensory adaptations unaddressed. We CT scanned a well-preserved skull of *Rhabdognathus*, a Paleocene dyrosaurid from Mali. We focused on three specific internal structures: the cranial endocast; inner ear; and paratympanic sinuses. The *Rhabdognathus* endocast showed novel features including a dorsal venous system that appears to communicate with the external skull table, enlarged tympanic bullae that meet at the endocranial midline, and elongate olfactory tracts forming half the total endocast length. The tracts end in paired olfactory bulbs with complex bony projections—a unique morphology perhaps serving to increase surface area for olfaction. *Rhabdognathus* has a novel conformation of its paratympanic system. The anterior and posterior divisions of the lateral Eustachian canal meet outside the skull and a unique duct was discovered connecting the pharynx to the adductor chamber. These findings require a reinterpretation of the associated external foramina in dyrosaurids and potentially their close relatives pholidosaurids. The inner ear exhibits aspects of both *Pelagosaurus* and *Gavialis*. The common crus is spherical, as in *Gavialis*, but significantly expanded. The cochlear duct is shifted anteriorly as in *Gavialis*. The semicircular canals appear pyramidal as in *Pelagosaurus* unlike the spherical shape of crocodylians. This is the first time dyrosaurid braincase and neurosensory features have been examined using CT scans. Our work reveals novel morphologies in the ear, paratympanic sinuses, and olfactory bulb that may relate to dyrosaurid adaptation to a marine habitat.

P1-186 ERICKSON, I; VOLLMER, AC; MARCKEL, MC; MOODY, SP; HIEBERT, SM*; Swarthmore College, USA; *shieber1@swarthmore.edu*
Gut Microbiota of Sympatric Migratory and Resident Hummingbirds
The mammalian gut microbiome is important to food utilization, nutrient recycling, fattening, and overall host health in addition to being implicated in stress-responsiveness and anxiety-like behavior. The bird microbiome has been understudied, and hummingbirds have been cited as an important study system because of their rapid metabolism, nectarivory, and high sucrase activity. Additionally, some fatten seasonally for annual long-distance migration (e.g., rufous hummingbird, *Selasphorus rufus*) whereas others (e.g., Anna's hummingbird, *Calypte anna*,) are year-round residents undergoing much smaller annual changes in fat stores. Rufous and Anna's hummingbirds were captured in the San Juan Islands (WA, USA) from May through August, weighed and scored for fat accumulation; cloacal fluid (CF) and feces were collected opportunistically (at known times post-capture) in microcentrifuge tubes. OTUs were identified from the V3-V5 region of 16s rDNA to approximately species level. Core microbiota (phyla present in > 95% of samples) included Actinobacteria, Proteobacteria, Cyanobacteria, and Firmicutes, but not Bacteroidetes. The relative abundance of 6 bacterial phyla varied with fat score, but the ratio of Bacteroidetes to Firmicutes, commonly found to vary with obesity in mammals, did not, perhaps because of rapid cycling of fat score within the migratory phase. Despite compositional differences, however, the predicted functional profiles of hummingbird gut microbiomes were largely conserved, indicating that compositionally distinct microbiomes can maintain similar functions. Further analyses will examine relationships among species, annual phase, fat score, fecal microbiota structure, CF corticosterone, and tonic immobility, a potential behavioral correlate of stress responsiveness.

137-2 ERKENBRACK, EM*; THOMPSON, JR; Yale University, University of Southern California; *eric.erkenbrack@yale.edu*
To be or not to be homologous: Evolution of cell type identity of the echinoderm larval skeletogenic cell
Cell types have diversified prodigiously since the dawn of multicellularity. During development, cell types are specified by cohorts of transcription factors interacting with cell-type specific genomic regulatory elements, which together approximate cell type identity. During evolution, cell type identity has been rigid enough to maintain highly conserved cell types but also labile enough to generate novel cell types. Hence understanding the evolution of cell type identity is key to explaining how ancestral cell types diversified to give rise to what we see today. Here, we tracked cell type identity of the echinoderm larval skeletogenic cell, a highly conserved and widely studied cell type that is characteristic of adult echinoderms and also early development of numerous echinoderm taxa. We used phylogenetic comparative methods to frame developmental spatial gene expression data in the context of cell type evolution. Our results show that, during the evolution of the echinoderm skeletogenic cell type, cell type identity was maintained in spite of differential transcription factor usage, suggesting that genomic regulatory information is critical to the identity of this cell type. We conducted ancestral state reconstruction to ask whether the most recent common ancestor of eleutherozoan echinoderms possessed a larval skeletogenic cell. Our analysis provided support for the presence of this cell type in larval development of the eleutherozoan MRCA, suggesting that all extant echinoderm larval skeletogenic cells are homologous and descend from a common ancestral cell type that was likely acquired in early development in stem eleutherozoans.

30-4 ESCOBAR-CAMACHO, D*; CARLETON, K; NARAIN, D; PIEROTTI, M; Department of Biology, University of Maryland, College Park, USA, Environmental Sciences, Anton de Kom University of Suriname, Paramaribo, Suriname, Naos Laboratories, Smithsonian Tropical Research Institute, Panama, Republic of Panama; *descoba2@umd.edu*
The visual system of Characiformes: a window to the teleosts lineage
Evolutionary biology aims to understand the origins and adaptations of animal sensory systems because they play a vital role in organismal fitness. Visual systems in teleosts are suitable for the study of evolution because of their remarkable variation in visual sensitivities. This is due to the presence of several visual pigments, light-absorbing molecules based of a chromophore and an opsin protein. Opsin diversity is a product of the dynamic evolution involving gene duplication, gene loss, pseudogenization and gene conversion. Characiformes, with more than 2000 described species, is a diverse group of freshwater fishes inhabiting a wide range of ecosystems. Their Gondwanan origin, species richness and colorful patterns, make them an ideal group for studying visual systems and their adaptations. In this research, we disentangle the visual system of Neotropical Characiformes, through RNA-sequencing and physiological experiments. Our results show that species differ in opsin gene complements and that Characiformes exihibit opsin gene duplications in both long wavelength sensitive (LWS) opsins and rhodopsin (RH1) genes. Phylogenetic analyses suggest that the LWS and RH1 duplicates are paralogs, and the product of the teleost whole genome duplication presumably after their divergence with the spotted gar. Furthermore, through gene expression analysis and microspectrophotometry, we show that the duplicated LWS opsins have undergone neofunctionalization as they are differentially expressed in the retina and shift in spectral sensitivity to shorter wavelengths.

P1-134 ESHLEMAN, M. A.*; KLUG, P. E.; GREIVES, T. J.; North Dakota State University, USDA-APHIS-WS, NWRC; *michelle.angelucci@ndsu.edu*

Costly Competing Investments: Does Spring Migration Distance Influence the Reproductive Hormones at Arrival to the Breeding Site in a Polygynous Species?

Early breeding individuals are often able to produce the most offspring; however, birds are unable to invest the energy to be fully prepared to breed when they are migrating long distances in the spring. Individuals wait until they arrive at the breeding ground to enter the final stages of reproductive preparation, but migration distance may be an important factor in determining when birds begin activating their reproductive systems. Previous studies have focused on males and monogamous species to investigate the relationship between migratory distance and reproduction. We propose that red-winged blackbirds (*Agelaius phoeniceus*), a polygynous species, are an ideal subject to study this relationship because it is advantageous to be the first female breeding on a territory. The first female typically gets the best nesting location and more parental investment from the male. We captured individuals upon arrival to the breeding ground and obtained a blood and claw sample from both males and females. Females were injected with GnRH to measure their maximum production of the sex steroid hormone testosterone as an estimate of the pituitary and ovarian status. Stable isotopes of hydrogen obtained from the claw samples provide an estimate of each bird's overwinter location. Our study will explore whether migration distance, estimated using stable isotopes, plays a role in the activity or responsiveness of the reproductive endocrine axis upon arrival to the breeding ground.

P1-239 ESPINOSA, AJ*; SPAGNA, JC; William Paterson University; *espinosaa6@student.wpunj.edu*

Phylogenetics of Holarctic Agelenine spiders using an augmented barcode strategy

Spiders in the family Agelenidae, and particularly the Agelenine subfamily, is common in Holarctic faunas, with 1287 species described in 80 genera. The growth of DNA barcoding allowed us to gather a broad dataset of Agelenine taxa, representing 20 genera in the subfamily, and covering nearly the geographic range of the group, including North America, Europe, and Asia. We developed a core taxon set (30 individuals from 9 genera representing North America, Europe, and Asia) with data from between 3 and 6 mitochondrial and nuclear loci, combining lab data, previously published data, and newly generated sequences. We subsequently added databased barcode sequences from 83 additional individuals. We performed Bayesian MCMC analysis, using a GTR+I+G model for 50,000,000 generations, to estimate a phylogeny for the Ageleninae and Tegeneriinae, with an orb-weaver as outgroup. The North American taxa split into two groups, a clade including the Western and Central American genera, and one including the widespread and Gulf Coast genera, and thus the continental assemblage of Agelenines appears diphyletic, but neither of these groups' affinities with European taxa were resolved with statistical support in the Bayesian analysis. Subsequent tree-searches using alternate criteria showed little improvement in resolving the polytomy of these three major groups.

P2-139 ESTES, SK*; AUSTIN, MC; MANDELARE, PE; PAIG-TRAN, EWM; LOESGEN, S; STROTHER, JA; Oregon State University, California State University, Fullerton; *estess@oregonstate.edu*

The Microbiota of Marine Fishes Produce Neuroactive Secondary Metabolites

Most vertebrate animals have complex interactions with their gut and surface microbiota. In marine fishes, mucus samples have been found to have potent antibacterial, antifungal, and anti-proliferative properties. Some of this activity has been attributed to chemical defenses from the host, but recent exploration of fish microbiota has shown that they also produce numerous bioactive secondary metabolites, small organic compounds that are not directly involved in primary metabolism. The resulting mixture of bioactive compounds within the microbiota environment is believed to have an important role in providing for host defense as well as shaping the composition of the microbial community. However, relatively few studies have examined whether the microbiota in marine fishes also produce neuroactive compounds. To address this question, we sampled surface mucus from dozens of marine fishes, isolated 47 unique bacterial strains, cultured these strains, extracted secondary metabolites from the cultures, and then tested extracts for neuroactivity using a zebrafish based behavioral assay and for cytotoxicity using a cell-based assay. We identified numerous microbial strains from several marine fish species that produce compounds with potent pro-nociceptive and cytotoxic properties. Such compounds may alter the behavior of the host organism or potentially have a role in preventing predation.

P1-127 ESTRADA, AD*; WILSTERMAN, K; COMIZZOLI, P; BENTLEY, GE; UC Berkeley , UC Berkeley, Smithsonian Conservation Biology Institute; *allegradestrada@gmail.com*

Sex steroids alter 3D growth of feline endometrial cells in vitro

Endometrial cells lining the uterus are critical for pregnancy success. These cells support implantation and early placental development. In humans, the sex steroids estradiol(E_2) and progesterone(P_4) modulate endometrial cells by stimulating proliferation, altering cell function, and directing cells to form glands in the uterine lining in preparation for blastocyst implantation. However, the pattern of sex steroid production across the reproductive cycle varies in other animals. For example, in humans estradiol remains elevated above baseline after ovulation, whereas estradiol in the domestic cat drops to baseline (<20 pg/mL). We are interested in whether sex steroids regulate feline endometrial cell growth and organization. We cultured isolated endometrial cells in a 3D in vitro system and treated them with E_2 and P_4 at concentrations corresponding to different periods in the estrous cycle. We also treated cells with E_2 or P_4 alone to determine whether these steroid hormones act independently. From images of the treated cells, we quantified morphological changes in cell growth. Steroid hormone treatment decreased the size of 3D structures formed in vitro (AOV, $P < 0.001$; Tukey's HSD: $P < 1.6e-5$). However, progesterone alone increased the number of 3D structures relative to the estradiol treatment (AOV, $P < 0.05$; Tukey's HSD: $P < 0.003$). Analysis of mixed steroid treatments are on-going; however, our findings thus far suggest that feline endometrial cells respond to sex steroids in similar ways to humans. We are using quantitative PCR to measure the expression of genes related to endometrial tissue function, which will further validate that cell organizational changes reflect functional shifts that occur in response to steroids.

P3-3 ETZEL, R*; KHORIATY, J; ELLERS, O; JOHNSON, AS; Bowdoin College; *retzel@bowdoin.edu*

The contribution of morphological characteristics on the bouncing gait of sea stars: A cross-species comparison

While sea stars are known to exhibit a crawling gait, they also exhibit a bouncing gait, observed in at least five species of sea stars. This bouncing gait (periodic vertical motion with associated horizontal variation in speed) is characterized by coordinated movement of a sea star's podia, or tube feet, and an overall increase in speed from the crawl. Here we focus on how the locomotion-relevant geometric scaling of individuals changes with size, and how various morphological differences (such as arm length, ambulacral area, animal density, and height) can inform differences in bouncing behavior between species. To study this, three species of sea star (*Protoreaster nodosus, Asterias forbesi, Luidia clathrata*) were filmed in recirculating seawater flow tanks using two cameras to provide paired views from the bottom and side. Tracker software was used to gather raw position and time data, which were processed using Mathematica to determine parameters such as maximum speed and bouncing frequency. We found *P. nodosus* and *L. clathrata* to be relatively dense sea stars with the ambulacral area from which podia emerge composing about 20% of their ventral surfaces, while *A. forbesi* is less dense, with an ambulacral area around 40%. *P. nodosus* is a tall sea star, while *L. clathrata* is flat and long-armed. With respect to locomotion, *L. clathrata* bounced at a higher frequency and attained speeds more than five times that of *P. nodosus*, while *A. forbesi* bounced at intermediate speeds and frequencies. Further, we found a positive correlation between maximum velocity and size for *A. forbesi* and *P. nodosus*, while *L. clathrata*'s velocity decreased with size. *P. nodosus* and *L. clathrata* both have scaling coefficients consistent with the inverted pendulum model, while *A. forbesi* does not.

S8-7 EVANS, KM*; TAYLOR, S; FENOLIO, DB; University of Minnesota, San Antonio Zoo; *jacksonk@umn.edu*

Bony patchwork: Mosaic Patterns of Evolution in the Teleost Skull

Mosaic evolution refers to the pattern whereby different organismal traits exhibit differential rates of evolution; typically, due to reduced levels of trait covariation through deep time (i.e. modularity). These differences in rates can be attributed to variation in responses to selective pressures between individual traits. These differential responses to selective pressures can also facilitate functional specialization allowing certain traits to track environmental stimuli more closely than others. The teleost skull is an excellent system for which to study mosaic evolution as it is comprised of a complex network of bones; each of which may be experiencing different selective pressures and constraints. Here we use three-dimensional geometric morphometrics to investigate patterns of mosaic evolution in the skull and jaws in a clade of Neotropical electric fishes (Apteronotidae: Gymnotiformes). We find strong support for a three-module hypothesis that consists of the face, braincase, and mandible and we find that the mandible has evolved four times faster than its neighboring modules. We hypothesize that the functional specialization of the mandible in this group of fishes has allowed it to outpace the face and braincase and modularize over time. We also hypothesize that this pattern of mosaicism may be widespread across other clades of teleost fishes.

S7-3 EVANS, KM*; WILLIAMS, K; WESTNEAT, M; University of Minnesota, University of Chicago; *jacksonk@umn.edu*

Do coral reefs act as a crucible for morphological innovation? A critical reappraisal of the effect of coral reef habitats on the evolution of morphological diversity in wrasses in the era of big data.

Coral reefs are complex marine habitats that have been hypothesized to facilitate functional specialization and increased rates of functional and morphological evolution. Wrasses (Labridae: Percomorpha) in particular, have diversified extensively in these coral reef environments and have evolved adaptations to further exploit reef-specific resources. Prior studies have found that reef-dwelling wrasses exhibit higher rates of functional evolution and higher functional disparity that non-reef dwelling wrasses. Here we re-examine this hypothesis across 180 species using high-resolution morphological data in the form of micro-CT scans and use three-dimensional geometric morphometrics to quantify shape differences in the skull and jaws across reef and non-reef dwelling wrasses. We find that reef-dwelling wrasses are both more morphologically disparate and exhibit higher rates of morphological evolution than their non-reef dwelling counterparts. Our results corroborate with previous studies and suggest that coral reef habitats act as crucibles for morphological innovation and diversification.

2-5 EVANS, AE*; URBAN, MC; JOCKUSCH, EL; University of Connecticut; *annette.evans@uconn.edu*

The Effect of Incubation Temperature on the Plasticity of Embryonic Development and Color Expression in Plethodon cinereus

Phenotypic plasticity can be a crucial adaptive response to climate change, particularly for dispersal-limited species living in fragmented habitats. In many amphibians, factors such as developmental temperature can induce plastic responses in general developmental traits such as growth rate and time to metamorphosis. For example warmer developmental temperatures typically cause increased growth and development rate thus a shorter time to reach metamorphosis. Plasticity has also been observed in the expression of color and patterns in amphibians, suggesting that plasticity may explain some of the spatial variation in relative frequency of alternative color morphs in natural populations. In the forests of northeastern North America, populations of red-backed salamanders (*Plethodon cinereus*) show differing proportions of two main color morphs, striped and unstriped. Although the color polymorphism has a genetic basis, plasticity may also contribute to the observed variation. We used a split-clutch common garden experiment to test the effects of developmental temperature on the growth, development and phenotype (color) of *P. cinereus* from six different populations across two states. Our results show promising evidence for temperature-induced plasticity in coloration of *P. cinereus* hatchlings. Surprisingly, we did not detect any temperature effects on hatchling size or any relationship between initial egg size and hatchling size. Given that the ecological and evolutionary drivers of the two morphs remain poorly understood, our study provides important insights into if and how polymorphic populations might be impacted by climate change across the range of this ecologically important species.

S2-3 EZENWA, Vanessa O*; CYR, Jennifer L; GAWRILUK, Tom R; KIMANI, John M; KIAMA, Stephen G; SEIFERT, Ashley W; University of Georgia, University of Kentucky, University of Nairobi, University of Kentucky; *vezenwa@uga.edu*

Trade-offs between immunity and life-history shape cryptic immunological variation in regeneration-competent rodents

Aspects of animal life history can constrain immune function, and biases in components of the immune response are often tightly coupled to variation in individual life history. Structural regeneration of external tissues, whereby organisms completely restore damaged tissue in lieu of repair and scarring, is an extremely rare life-history trait in mammals. One hypothesis put forward to explain the rarity of tissue regeneration in mammals is that there are inherent trade-offs between mammalian immunity and tissue regeneration, but this idea has yet to be rigorously tested because of the lack of a suitable model system. Taking advantage of a unique study system, the African spiny mouse (Acomys spp.), for which genuine tissue regeneration was recently described in wild, pathogen-exposed, immunocompetent adults, we tested the hypothesis that regeneration imposes constraints on immune function. We used a comparative immunological approach to examine variation in cellular and humoral components of the innate immune response in regeneration-competent spiny mice and regeneration-incompetent laboratory and wild mice. Our results suggest that subtle differences in spiny mouse immunity may facilitate the maintenance of the regeneration phenotype.

P1-163 FABER-HAMMOND, J; O'ROURKE, C; RE, SCP*; RENN, Susan; Reed College Biology Department; *renns@reed.edu*

Neural gene expression profiles integrating feeding and care circuits in the mouth-brooding African cichlid fish A. burtoni

The most fundamental life history trade-off lies at the intersection of current versus future reproductive output. Resources that are dedicated to current offspring become unavailable for somatic maintenance or future reproduction. For most species, the diverse set of activities that compose "feeding" and "parental care" must be co-regulated through partially overlapping neuroendocrine circuits, and evidence indicates substantial cross-talk between these circuits in at least some species. To identify the mechanisms integrating these two pathways, the expression of feeding-related and care-related circuits should be studied under various conditions that would necessitate adjustment in the tradeoff. Sites of integration mechanisms will be indicated by changes in care-related circuits under varying conditions related to energy budget such as food availability. We study maternal mouth-brooding in the cichlid fish *Astatotilapia burtoni*, an independently-evolved instance of robust care. The neural circuits regulating maternal behavior are inextricably linked with the feeding circuits to allow voluntary starvation despite significant loss of body mass. We use two different *A. burtoni* fish stocks, one an inbred lab stock inadvertently artificially selected for rapid reproduction and low maternal investment and the other a recently collected wild stock that displays a rich repertoire of maternal care and resistance to starvation induced loss of body condition. We measure behavior, morphological changes, hormone profiles and neural gene expression patterns throughout the brooding cycle comparing between the two stocks to identify key mechanisms associated with the adaptive regulation of care and feeding.

P2-35 FABIAN, JM*; MAEDA, M; SIWANOWICZ , I; WALKER, S; BOMPHREY, R; LIN, HT; Imperial College London, Royal Veterinary College, HHMI Janelia Research Campus, University of Leeds; *j.fabian@imperial.ac.uk*

Toward the Neural Representation of Aeroelasticity in Insect Wings

Dragonflies are acrobatic insects that perform critical tasks in flight, such as hunting, mating and navigation. Their wings undergo large, periodic, deformation on each flapping cycle. This aeroelastic response is determined by the interaction of inertial and aerodynamic loads as well as the detailed architectural and material characteristics of the wings. Flying insects detect mechanical strains within the wing via sensory structures called campaniform sensilla embedded within the cuticle of the veins. Information encoded by the campaniform sensilla can be used to monitor instantaneous wing loads and control wing stroke kinematics. Here we combine several microscopy techniques to describe the distribution of campaniform sensilla on the dragonfly wing. The sensory information perceived by each sensillum is largely dependent on its position on the wing, and its own mechanical structure. By identifying the position of campaniform sensilla across the dragonfly wing we can predict how aeroelastic loads are monitored during flight. Additionally, to understand natural loading conditions during free flight we have reconstructed 3D moving and deforming wing geometries based on high-speed recordings subjected to voxel carving. These data are informative for electrophysiological and modelling studies of dragonfly flight.

136-3 FABRE, A-C*; BARDUA, C; BONNEL, J; BLACKBURN, D; GOSWAMI, A; NHM, London, Univ. of Florida, Florida; *fabreac@gmail.com*

Morphological Integration of the Head in Salamanders: Impact of Developmental Strategy and Ecology.

Caudata display a great diversity of developmental strategies directly impacting their morphology and the exploitation of their environment during their ontogeny. Several different developmental strategies have evolved independently during the evolution of Caudata. For example, some species exhibit direct development, hatching directly as a terrestrial phenotype, whereas others are paedomorphic, keeping aquatic larval traits even if they are reproductively active. Others species have a complex life cycle with bi-phasic development, allowing them to exploit different environments during morphologically different life history stages. The aim of this study is to test the impact of the complexity of life cycles and ecology on the cranial shape evolution. To do so, high-density geometric morphometric and integration methods were performed to characterize the shape of 14 regions of the cranium for 145 species spanning the full phylogenetic, ecological, and developmental breadth of Caudata. Each cranial region was analysed separately to detect mosaic evolution and test for a relationship between magnitude of integration, morphological disparity, and evolutionary rate. Morphological integration, modularity, and disparity analyses were carried out in order to test if a complex life cycle promotes phenotypic disparity and modularity, whereas paedomorphic or direct development strategies promote morphological integration and constrain shape variability. Finally, rates of shape evolution were calculated for each developmental strategy in order to test increased or decreased rates of evolution were associated with complexity of life cycle. Specifically, if a complex developmental strategy tends to constrains cranial shape, then an implication of the developmental strategies should increase the evolutionary rate of the cranium.

P1-227 FAHEY, C*; FARADY, S; FREDERICH, M; University of New England, Biddeford, ME; *cfahey2@une.edu*

Vulnerability of coupled Social-Ecological System (SES) revealed in case study of local management of softshell clam industry

A coupled Social-Ecological System (SES) approach can be used to manage the interactions between people and their environment and is the standard for Maine's Fisheries management programs. This allows coastal communities to exert direct management of resources with a focus on responsible use of the coastline, ensuring its future viability. Management and conservation goals for the soft shell clam *Mya arenaria* industry are linked to economic needs. State law requires municipalities with commercial shellfish operations to develop a management program, approved by the Department of Marine Resources. These plans specify conservation work required for license holders to maintain their licensure. Some state-recommended conservation work include population surveys, seeding, spat collection, and predation deterrents, as currently implemented by most municipal shellfish committees. We investigate and evaluate one shellfish conservation program and its impacts on management implications. Using surveys, engaging local clammers, and conducting field work, we found that local interpretation of these mandates fall short of their intended goals, despite adhering to state requirements. Specifically, despite clammers and shellfish managers investing significant time and money in their conservation program, no reliable clam population data is produced, leading to a lack of solid data to inform sustainable resource management. This illustrates that a coupled SES approach for shellfish management can produce large vulnerability in resource management that could result in mismanagement and deterioration of the respective resource.

P1-196 FAIR, T*; GARDNER, M; INGRUM, I; NOONAN, K; CHILDRESS, M; Clemson University; *tfair@g.clemson.edu*

Effects of Hurricane Irma on reef community structure in the Florida Keys National Marine Sanctuary

Coral reefs provide structurally complex habitats for thousands of species of marine organisms. The increased energy of hurricanes has the potential to impact reef fish density, richness or behaviors by altering physical structure or substrate composition. In September, a category 4 hurricane (Hurricane Irma) made landfall in the Florida Keys causing widespread impacts on the Florida reef tract. In this study, we compared pre and post surveys of substrate composition (photo quadrants) and reef fish densities (video transects) on three reefs that varied in proximity to the point of impact. Substrate cover after the hurricane was marked by noticeable decreases in algal cover, particularly turf algae, and increases in sand and coral cover. The impact on abundance within fish feeding groups was inconsistent over the three sites. The initial effects of the hurricane impacted substrate on a varied scale across the reefs, leaving them open to differing coral-algal dynamics as the area is resettled.

P1-130 FALSO, MJS*; SHIDEMANTLE, GI; PASQUALE, VE; CAMPBELL, ZI; GUSTAFSON, KL; MARSHALL, LV; FALSO, PG; Slippery Rock University; *miranda.falso@sru.edu*

Photographic Examination of Nuptial Pads in Xenopus laevis Exposed to the Pesticide Imidacloprid

Amphibians are extremely sensitive to environmental conditions and populations are experiencing widespread and rapid declines in recent years. Numerous studies suggest that chemical contaminants and disease present immediate threats to amphibian populations worldwide. In addition to directly killing amphibians, contamination of aquatic environments with chemicals has been linked to sublethal disruptions of the endocrine and immune systems. This study examined the impact of chronic exposure to a neonicotinoid pesticide on amphibian development and secondary sex characteristics. Neonicotinoids are widely used to kill insect pests by mimicking nicotine and disrupting function of the nervous system. *Xenopus laevis* were chronically exposed to environmentally relevant concentrations of the neonicotinoid, imidacloprid. Following sexual maturity photographs were obtained of the forelimb area containing the nuptial pad. The nuptial pad contains keratinized hooks and breeding glands sensitive to androgens. Methodology is currently being developed to evaluate intensity and size of nuptial pads following treatment. Imidacloprid has been indicated to impact male reproduction in other species, therefore valuable data may be obtained to aid in understanding the impact of imidacloprid on amphibian reproduction.

P3-182 FAMUYIWA, T; Florida Atlantic University; *tfamuyiwa2014@fau.edu*

ABC Transporter Mediated Multidrug Resistance in Prostate Cancer

Background: Prostate cancer (PCa) is the second most diagnosed cancer in men. The high incidence of prostate cancer has been attributed to failures in conventional chemotherapy. Studies suggest that energized ATP Binding Cassette proteins cause 50% of the failure in chemotherapy. This study focuses on the inhibition of ATP Binding Cassette (ABC) protein mediated drug resistance in prostate cancer treatment. Specifically, Poly Lactic-co-Glycolic Acid (PLGA) nanoparticle will be utilized as carrier to deliver SC-514 and 3-Bromopyruvate (3-BPA) in various PCa cell lines. Objective of study: This study aims to: (i) investigate the potential interaction between 3-BPA and SC-514 Method: The bioassays used in this study include: trypan blue exclusion, MTT tetrazolium, NBT, LDH cytotoxicity, cell titer glow, multidrug resistance efflux Results: ROS level of LNCaP cells treated with 3-BPA ($r = -0.5$, $p = 0.11$), SC-514 ($r = -0.72$ $p = 0.04$,) and 3-BPA + SC-514 ($r = -0.58$, $p = 0.04$) showed no significant difference in ROS modulation ($p = 0.54$). Results also, suggested a weak ($r = -0.29$) to moderate ($r = -0.42$) negative correlation between ROS released and cell death. In addition, there was a weak correlation ($r = 0.19$) between percentage ROS induced and percentage apoptotic death. There was a positive correlation between the concentration of drug and cell death. Results based on cell titer glow assay suggested that 3-BPA and/or SC-514 depleted intracellular ATP in DU-145 cells and PC-3 cells. SC-514 and/or 3-BPA are substrates for MDR1. 3-BPA and/or SC-514 potentially block MDR1. Conclusion: 3-BPA and SC-514 has the potential to inhibit multidrug resistance by reducing the intracellular ATP available to ATP Binding Cassette proteins. Apoptotic induction in DU-145 and PC-3 prostate cancer cells appears to occur via a mechanism other than reactive oxygen species (ROS) induction.

25-1 FANNJIANG, C*; KAKANI, K; Research and Development, Monterey Bay Aquarium Research Institute, Moss Landing, CA; Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, CA, Research and Development, Monterey Bay Aquarium Research Institute, Moss Landing, CA; *clarafy@berkeley.edu*

Using machine learning to deduce fine-scale behavior of jellyfish (Chrysaora fuscescens) in Monterey Bay

Jellyfish are increasingly of interest to researchers due to their poorly understood behavior and ecosystem impacts. Understanding jellyfish locomotion and movement ecology has been hindered by the difficulty of attaching biologgers to gelatinous tissue. Previous biologging studies of jellyfish have used the "tether method" to recover tags, in which tagged animals are attached to drifters transmitting location information. Although this method imposes restrictions on the animal's movement, its precise effects have never been quantified, thereby compromising research findings. Here we develop novel machine learning methods to 1) identify uninfluenced portions of the tag data and 2) classify fine-scale jellyfish behavior. We deployed the ITAG, a biologging package with motion and environmental sensors, on 8 *Chrysaora fuscescens* in Monterey Bay. By collecting simultaneous video footage of the tagged organisms with a remotely operated vehicle, we were able to train machine learning classifiers to identify periods of tether influence and animal swimming, drifting, and turning. We used these tools to (1) characterize the heading over time of *C. fuscescens* relative to a drogued drifter, (2) estimate *in situ* jellyfish activity, finding that animals actively swim more than 97.5% of the time, and (3) deduce that turning is more energetically costly than straight swimming. Our work demonstrates how machine learning methods can help maximize the insights yielded by biologging, and contributes new techniques for understanding fine-scale *in situ* animal behavior.

83-5 FARALLO, VR*; MUÑOZ, MM; Virginia Tech; *vfarallo@gmail.com*

Mountaintop endemics and climate change: is warming really a problem?

Climate change is occurring worldwide, but the impacts of change are not predicted to be equal among organisms. For example, mountaintop endemics are expected to be particularly susceptible to warming because they are thought to be adapted to relatively cool conditions and, as conditions warm, will have nowhere to flee. Many of these predictions are based on correlative modeling approaches, which assume or treat species as physiologically adapted to their local conditions. Mechanistic niche models, in contrast, incorporate data of species' behavior and physiology to predict when a species can be active. Here we demonstrate that behavioral thermoregulation can buck expected trends in species distributions under climate change. We present the results of correlative and mechanistic niche models for three species of *Anolis* lizards from the island of Hispaniola, one widespread species *A. cybotes,* and two mountaintop endemics, *A. armouri* and *A. shrevei*. Correlative models predict a significant decrease in range size of both mountaintop endemics to near extinction levels, with the range size of the widespread species staying constant under climate change. In contrast, mechanistic niche models predict increased activity for mountain endemics, including beyond their current ranges. The mechanistic model also predicts increased activity for the widespread species, *A. cybotes*, within the range of the mountaintop endemics. Our results suggest that climate change will increase the thermal suitability of their current ranges, both for montane endemics and their lowland competitor. As such, montane endemics may be at risk of extinction, but not as a direct result of temperature changes, but rather through the indirect effects of biotic interactions.

134-3 FARGEVIEILLE, A*; REEDY, A M; MITCHELL, T S; DURSO, A M; DELANEY, D M; PEARSON, P R; WARNER, D A; Auburn University, Auburn, University of Virginia, Auburn University Auburn/ University of Alabama, Birmingham, Utah State University, Logan, University of Alabama, Birmingham/ Iowa State University, Ames, Auburn University Auburn/ University of Alabama, Birmingham, Auburn University Auburn/ University of Alabama, Birmingham/ Iowa State University, Ames; *akf0020@auburn.edu*

Population Demographics of an Invasive Lizard Following Experimental Introduction on Small Islands

Human activities have increased the number of species introductions into non-native ranges. After introduction, some populations grow rapidly in new environments and can affect local biota. We were interested in describing patterns of population demographics during the colonization and establishment stages following the introduction of a non-native lizard species (*Anolis sagrei*). We released adult lizards onto three small islands prior to the reproductive season and monitored their survival and reproduction over the first reproductive season. Subsequently, to gain insight into the establishment of these introduced populations, we examined the survival and reproduction of the descendants of the founding populations over the following two years. We found variation among islands for survival and reproductive rates of founders, which affected the patterns of juvenile and adult recruitment at a local scale. We also found variation across seasons in survival rate, with different patterns among islands. Our results demonstrate that survival and reproductive rates can vary at local scales affecting the ability of this species to colonize new environments. This fine-scale variation in survival and reproductive rate across islands has important implications for the likelihood of population establishment after colonization.

S8-1 FARINA, SC*; KANE, EA; HERNANDEZ, LP; Howard University, Georgia Southern University, George Washington University; *ekane@georgiasouthern.edu*

Multifunctional Structures and Multistructural Functions: Functional Coupling and Integration in the Evolution of Biomechanical Systems

The goal of many functional biologists is to understand how the structural components of an organism affect its ability to survive in a given environment. However, the links between form and function may be complex, such that the same structure or set of structures can contribute to multiple functional outputs or that a given functional output may rely on contributions from multiple structural components. In each case, integration between structures and functions is necessary to match organismal output with ecological demand. Therefore, the emergent integration of form and function is important for understanding the drivers of evolutionary change among organisms. This symposium brings together diverse researchers at the forefront of this research area to provide a range of examples demonstrating the broad applicability of these ideas, discuss methods and approaches for addressing complex form-function relationships, and provide insight into the role of selection in driving changes in structures and the links between structures and functions. These discussions will provide the background for a final discussion on new hypotheses and recommendations for future work in this field.

S8-5 FARINA, SC; Howard University; *stacy.farina@gmail.com*
Is functional coupling really so constraining? The role of coupling in the evolution of functional anatomical systems

How do evolutionary processes act upon structures that are involved with more than one biomechanical system ("functional coupling")? Functional coupling has long been thought to constrain morphological evolution, and yet evidence to support this assertion includes only a small number of studies that show increased morphological diversification when functions become decoupled and decreased morphological diversification with the appearance of a new coupling. While these studies are certainly compelling, the question becomes: Does functional coupling always (or even frequently) constrain morphological evolution? To address this question, I define a series of terms to provide a framework for considering morphological evolution in structures that perform multiple functions. I then discuss examples of functional coupling associated with morphological innovation and novelty that have resulted in increased morphological diversification. Finally, I present a study on the evolution of suction feeding and gill ventilation in fishes using measurements from micro-CT scans to demonstrate how sources of relaxed morphological constraint can operate within a system of closely-coupled functions.

S8-12 FARINA, SC; Howard University; *stacy.farina@gmail.com*
Panel Discussion: New Perspectives on Integration in Functional Morphology

We are moderating a panel discussion on future directions for the study of integration in the fields of functional and evolutionary morphology. Topics will include: What tools and datasets are currently available that can be leveraged for studies of functional and evolutionary integration? Which broad goals and directions in our field should we be pursuing? How can we clarify and standardize terminology to make the field more accessible to broader audiences? How can we better communicate the study of integration, which is often jargon-heavy, to the public? Panelists will be Drs. Anjali Goswami, Kory Evans, Tristan Stayton, and Luz Patricia Hernandez.

P3-16 FARLEY, GM*; BEDORE, CN; PATEK, SN; Duke University, Georgia Southern University; *gmf7@duke.edu*
Rapid hydrostatic tentacle protrusion in cuttlefish

A diversity of organisms rapidly protrude prehensile appendages to capture prey, including the tongues of lizards, salamanders, and frogs, and the tentacles of squid and cuttlefish. Cephalopods provide an interesting comparison to land-dwelling reptiles and amphibians, because the buoyancy of water can support greater appendage mass, yet drag costs are higher in water than in air. Using high-speed imaging (1000-3000 frames/s), we analyzed the strike behavior and kinematics of two species of cuttlefish, *Sepia bandensis* (n=6 individuals) and *Metasepia pfefferi* (n=3 individuals). Although both species have similar body sizes, *S. bandensis* have short, wide tentacles that they extend up to 2 times their body lengths, while the longer and slimmer tentacles of *M. pfefferi* can be extended up to 2.5 body lengths. Their tentacle extension exceeds rapid appendage protrusion in other species (maximum reported is 1.5 body lengths in *Chameleo*). In terms of strike kinematics, *S. bandensis* (34 strikes) reached lower maximum velocities (3 m/s) and accelerations (2000 m/s^2) than *M. pfefferi* (4 m/s; 4000 m/s^2; 14 strikes). Both cuttlefish species exceed the maximum velocities and accelerations reported for the squid *Loligo pealei* (2.3 m/s; 250 m/s^2). *M. pfefferi*'s maximum velocities are comparable to the chameleon *Chameleo outstati* (4.9 m/s) and both cuttlefish species exceed the chameleon's 392.8 m/s^2 maximum acceleration. These findings suggest that the physical properties of water allow cuttlefish to achieve impressive velocities while extending soft, minimally-supported appendages much farther than their land-dwelling counterparts.

139-7 FARMER, CG*; CIERI, RL; PEI, S; University of Utah/Trinity College Dublin, University of Utah; *cg.frmr@gmail.com*
A Tesla Valve in a Turtle Lung

We have known for a long time that the lungs of birds contain aerodynamic valves and one way airflow through most of their conducting airways, and more recently that crocodylians and some lizards also have unidirectional flow. These latter data raise questions about the full phyletic distribution of aerodynamic valves and the functional significance of these patterns of flow. Here we present data on patterns of airflow in the lungs of a turtle, the red-eared slider (*Trachemys scripta*). The pattern is distinct from the pattern observed in archosaurs and lizards. The lung consists of four, large lateral chambers associated with smaller medial chambers and a broad intrapulmonary bronchus that makes a zigzag pattern through the lung. Using an endoscope that was implanted into the lateral chambers, we visualized the movement of insufflated aerosolized lipids. In the lateral chambers, most of the flow occurred during inspiration, with flow sometimes completely stopping, and generally slowing during expiration. The particles moved in a clockwise direction in the left lung and a counterclockwise direction in the right lung, in dorsal view. CFD simulations of flow show that the gases are moving back and forth between medial and lateral chambers in a transverse figure eight. Fresh air first moves into the most cranial chambers and them makes its way caudad with subsequent inspirations. On exhalation, flow exits in a straighter path along the intrapulmonary bronchus. We found no evidence of intercameral perforations. Measurements of the pressure drop across the lateral chambers at a constant volume of flow but in opposite directions indicates there is greater resistance to flow during inspiration than expiration, and the ratio (diodicity) compared favorably to man-made micro-Tesla valves. The functional significance of this pattern of flow is currently unknown. Funded by NSF IOS CAREER-1055080.

P2-50 FASICK, JI*; SERBA, KM; The University of Tampa; *jfasick@ut.edu*
Whale Shark (Rhincodon typus) Retinal Pigments and Visual Foraging Ecology
The whale shark (*Rhincodon typus*) is the largest of all extant elasmobranchs (sharks and rays). Similar to the mysticete whales, whale sharks are filter feeders and spend most of their foraging time in surface waters at depths less than 10m. Whale sharks are also capable of diving to depths in excess of 1500m with speculations that these dives are also associated with foraging. Sequence analyses of the recently published *R. typus* genome was used to describe the whale shark retinal opsins. Results show that whale sharks are rod monochromats and lack cone photoreceptors, a trait that is also found in the filter-feeding mysticete whales. The absorbance maximum of the single rod visual pigment is estimated to be 500nm based on conserved amino acids at rhodopsin positions 83, 292 and 299. Thus, whale shark rhodopsin is spectrally tuned and adapted to surface foraging in pelagic waters and is relatively less sensitive to light at depths greater than 200m. Because *R. typus* lacks cone photoreceptors, the retinal pigment melanopsin, expressed in intrinsically photosensitive ganglion cells (ipRGCs), is critical for controlling the pupil light reflex (PLR) in photopic light conditions to protect the rod-only retina from photobleaching. Previous studies have shown that the phosphorylation sites found in melanopsin's carboxyl-tail are responsible for the activation/deactivation kinetics of ipRGCs expressing melanopsin, which control the rate of the PLR and pupil diameter under photopic conditions. Sequence analysis of the carboxyl tail from whale shark melanopsin reveals phosphorylation sites that are typical of a duplex retina (rods and cones) and are unlike other marine rod monochromats. This would result in a relatively fast PLR in whale sharks in stark contrast to the slow PLR described in rod monochromat whales.

39-2 FASSBINDER-ORTH, C*; HUGHES, S; SABOTIN, R; PUSH, G; TRAN, T; Creighton University; *carolfassbinder-orth@creighton.edu*
Honey Bees in Peril: An Investigation of Honey Bee Viral Infection Dynamics
Honey bee (*Apis mellifera*) colonies in the United States have suffered annual losses of up to 30% of total managed colonies over the past 10 years. Many factors likely contribute to these massive colony losses, including habitat destruction, pesticide exposure, migratory stress in long-distance pollination operations, *Varroa destructor* mite levels, and pathogen load. Colony collapse disorder (CCD) is the name given to the pattern of sudden colony loss and honey bee disappearance from colonies, and likely involves viral pathogens as a strong contributing factor. Honey bee viruses have generally not been culturable in laboratory conditions, making experimentation with these viruses difficult. Our laboratory has developed a model system to study viral infections in honey bees using Cricket Paralysis virus (CrPV). This virus can be cultured and quantified in the laboratory, alters honey bee physiology and behavior and increases the death rate of worker bees. We measured multiple physiological and behavioral parameters in honey bees following viral infection, including fat content, vitellogenin expression, phenoloxidase levels, and radio frequency identification (RFID)-tracked behavior. Physiological measurements (fat content, vitellogenin expression, and phenoloxidase activities) exhibited age-dependent changes and were significantly different in bees infected with CrPV compared to uninfected bees. Additionally, the behavior of CrPV-infected honey bees was measured using micro RFID tags, and the behavior of CrPV-infected honey bees was determined to be significantly different from uninfected bees. This work provides a new model virus system to study honey bee infections and provides a direct, mechanistic understanding for how viruses cause physiological and behavioral changes in honey bees.

P2-84 FASSBINDER-ORTH, C*; HUGHES, S; Creighton University; *sch88437@creighton.edu*
Radio-Frequency Identification as a Tracking System: a study of honey bee behavior
With recent increases in colony losses and abnormal colony syndromes and behaviors (e.g. Colony Collapse Disorder), it has become more important than ever to examine honey bee (*Apis mellifera*) behavior. One challenge of studying honey bee behavior is to track them noninvasively, so the bees do not alter their normal behavior. To address this challenge, we developed an enclosed system that uses radio-frequency identification (RFID) to monitor honey bee behavior. The data gathered from the system can be used to create a spatial analysis model. The spatial analysis can be used as a predictive model to explain colony loss and determine potential outcomes for colonies. Moreover, it can be used to shed light on altruistic suicide which is a key characteristic of Colony Collapse Disorder. Each system had six RFID readers placed at a standardized distance of one another, and each bee was outfitted with a microchip programmed with a unique identification number (ID). Every reader in the system was attached to a small, single-board computer. The computer provided power to the reader and ran a python program that recorded each communication between its respective reader and microchips within threshold of the reader's antenna. Every time the reader detected a microchip, the ID and timestamp were appended to a text file stored on the computer. The text file was then analyzed to develop the statistical spatial analysis. This system has applications far beyond the scope of honey bee colonies. Because it is not invasive, this system can be used to track any animal that can be outfitted with a 2.5 x 2.5 millimeter microchip. Furthermore, animals that can support larger RFID chips can be tracked at a larger distance than the microchip used in this experiment, enabling the study of free-living organisms.

34-4 FATH, M A*; TYTELL, E D; Tufts University; *michael.fath@tufts.edu*
Using Perturbations to Study Locomotor Stability in the Bluegill Sunfish (Lepomis macrochirus)
Fishes regularly encounter unsteady and turbulent flows. These flows can perturb steady swimming and require the fish to make corrections in order to return to an unperturbed, stable swimming state. A fish's ability to return to steady state swimming after a disturbance is critical to swimming effectively. As such, the ability to stabilize can influence a fish's success in obtaining food, migrating, or avoiding predators. In terrestrial systems, locomotor stability has been studied by introducing an acute perturbation into an otherwise steady system. Here, we use the same concept to study stability in aquatic locomotion. We developed a miniature device that produced a brief jet of fluid of a known impulse. We then sutured the device to the dorso-lateral surface of bluegill sunfish (*Lepomis macrochirus*), just above the center of mass. We then perturbed the fish at different phases during its swimming motion and at different swimming speeds. We quantified the initial effect of the perturbation, which can cause rolling or lateral motion. After the perturbation, fish made small kinematic adjustments, but did not startle or perform dramatically different behaviors. The time it took the fish to return to steady swimming after the perturbation is used as a measure of stability.

S8-3 FEILICH, KL*; LOPEZ-FERNANDEZ, H; Univ. of Michigan; *kfeilich@umich.edu*

What do we assume when we ask ecomorphological questions?

Ecomorphology is "the study of the relationship between the functional design of organisms and the environment" (Wainwright, 1991). Ecomorphological approaches are becoming increasingly common, finding applications spanning macroevolution to wildlife conservation. Ecomorphology is inherently interdisciplinary: the choice and interpretation of morphometric data as descriptors of functional performance is informed by biomechanics, ecology, and behavior. In most cases, ecomorphological studies only draw on a subset of these disciplines. As a result, ecomorphological studies make a number of implicit assumptions that, while rendering their results no less valid or valuable, need to be considered when ecomorphology is used to ask evolutionary and ecological questions, or when it is relied upon to guide conservation or management policy. Central among these is the assumption of correlation between measured morphological traits and ecological performance. The validity of any conclusions derived ecomorphological studies depend on the assumptions made, explicit or implicit, when selecting morphological variables and the methods to analyze them. We will discuss different methodological and conceptual approaches taken by ecomorphological studies, and the implicit assumptions of each approach. Then, we will discuss various practices that can help support or eliminate some of the assumptions of ecomorphological studies. Ultimately, we attempt to foster a better understanding of the strengths and caveats of ecomorphological approaches in ecological, evolutionary and conservation studies, and suggest practices that may strengthen their results.

P1-140 FEINGOLD, SR*; ROARK, AM; Furman University; *sarah.feingold@furman.edu*

Using the Yeast Estrogen Screen to Measure the Estrogenicity of Personal Care Products

Many cosmetic and pharmaceutical products manufactured for daily use contain endocrine-disrupting compounds. These compounds can occur naturally (e.g. phytoestrogens) or can be man-made (e.g. UV filters or phthalates). Many bind to estrogen receptors, leading to sex reversal, infertility, menstrual irregularities, miscarriage, and breast cancer. The purpose of this study was to detect and quantify estrogenic compounds in a variety of personal care products, including shampoos, conditioners, lotions, sunscreens, and moisturizers, using the yeast estrogen screen (YES). Two strains of recombinant *Saccharomyces cerevisiae* containing plasmids that resulted in the expression of either the alpha or beta isoforms of human nuclear estrogen receptor (ER) were used to quantify ER agonism in ethanol extracts of 32 personal care products, each of which was measured in triplicate. Estrogenic compounds in a sample bound to the ER alpha or ER beta receptors, resulting in the dose-dependent expression of beta-galactosidase. The yeast cells were then lysed to release the beta-galactosidase, which cleaved a colorimetric substrate and produced a yellow to red product, with the degree of color change correlating to the concentration of estrogenic compounds. Of 32 personal care products tested, over half were positive for the presence of estrogenic compounds. The results of this study indicate that many popular personal care products contain estrogenic endocrine-disrupting chemicals and suggest that caution is warranted when using such products.

P2-61 FEIPEL, CW*; KROHMER, RW; Saint Xavier University; *krohmer@sxu.edu*

Mapping Aromatase Immunoreactive Neurons and Estrogen Receptors During Early Life Stages of Brain Development in Male Red-Sided Garter Snakes.

The Organizational/Activational Hypothesis states, exposure to androgens early in development organizes the male brain so that, as an adult, the same hormone elicits the expression of male reproductive behaviors. However, in the past several decades, studies have indicated that estrogens, aromatized from androgens, and not the direct action of androgens, may be critical for organization of the male brain. The presence of estrogens during prenatal and perinatal brain development has been shown to stimulate cell growth and promote the formation of neuronal and sex-specific pathways. It is believed that the estrogens that influences CNS development is derived from neuronal estrogen synthesis (aromatization) rather than estrogens found in the circulation. In a recent study, we found that estrogens appeared to be the active hormone regulating courtship and mating in the male red-sided garter snake (RSGS). Consequently, if estrogen is the hormone activating courtship and mating in male RSGSs, estrogens should also be responsible for organizing the male RSGS brain. We tested our hypothesis by examining the brains of newborns, 3, 6, and 9 month old RSGSs, raised under natural conditions in our lab, and wild-caught immature and juvenile RSGSs for the presence and distribution of aromatase immunoreactive (ARO-ir) neurons and estrogen receptors (ER) as indicators of brain development. Preliminary results support an age related progression where ARO-ir neurons and ERs, absent in newborns could be found in the brains of juvenile RSGSs.

P2-11 FEIPEL, CURTIS*; TATUM PARKER, TATIAN; Saint Xavier University; *tatum@sxu.edu*

Bisphenol A's impact on the germination and growth rate of Brassica rapa

The use of Bisphenol A (BPA) a synthetic high production volume compound used in plastics and epoxy resins has grown exponentially, while the consequences of this environmental contaminant is vaguely understood. Considering the ability of BPA to leach into its surroundings, along with its increased use, further studies are necessary to understand its comprehensive impact on the global system. Our study is concerned with the acute stress effects of BPA on terrestrial vegetation, by observing germination rate, root length, root behavior, and true leaf appearance in *Brassica rapa* (Wisconsin Fast Plant). Germination and early development were analyzed by continual exposure of seeds to BPA treatments of 0, 0.05, 0.25, 1, 10, 25, and 50 mg/L. Germination rate and success of germination showed no significant difference within or between any concentration. In our 48 hours post-germination measurements, the root lengths showed significant differences in mean length between treatments, with the 25mg/L and the 50mg/L treatments. The root behaviors observed were classified as normal or abnormal in their geotropic response, finding that in a concentration-dependent manner abnormal behavior increases. BPA is possibly interfering with auxin production and distribution in the root cap. The plants true leaf appearance at 96 hours decreased as the concentrations increased. The true leaf appearance provides a measure of plant health suggesting that the overall plant health declines as the concentration of BPA increases. The differences observed at the higher urban BPA concentrations may have significant effects on agriculture as well as wild plants. Further studies should be pursued to better understand the mechanistic and fitness effects of BPA.

S7-10 FELICE, RN*; TOBIAS, JA; GOSWAMI, A; University College London, Imperial College London, The Natural History Museum; *ryanfelice@gmail.com*

How Dietary Niche Shapes Macroevolution in the Avian Skull

Cranial evolution is hypothesized to be strongly linked to trophic ecology, as evidenced by such key examples as Galapagos finches and Hawaiian honeycreepers. However, this hypothesis is rarely tested at macroevolutionary scales. Here, we interrogate the relationship between diet, foraging ecology, and cranial phenotype across extant birds. We utilize high-dimensional geometric morphometric data (>700 3D landmarks) quantifying skull shape in 352 bird species, spanning the breadth of phenotypic variation in the crown group. We demonstrate that diet and foraging behavior are significant, but surprisingly very weak predictors of skull shape ($p < 0.001$, $R^2 < 0.09$). However, rates of evolution vary more substantially across dietary niches. This is especially pronounced in the face and cranial vault regions of the skull, where granivores and nectarivores exhibit the highest rates of evolution and terrestrial carnivores evolve the slowest. Other regions of the skull, including basisphenoid, occipital, pterygoid, and quadrate, show less pronounced differences among trophic guilds. These findings suggest that the strength of selection imposed by trophic ecology differs across skull regions/modules and across niches. Dietary groups with high rates of facial evolution are those that include strong mechanical constraints (crushing seeds) or geometric constraints (coevolution between flowers and nectarivores). Taken together, these results illustrate how dietary ecology and complex adaptive landscapes influence the tempo and mode of phenotypic evolution and how big-data approaches can inform our understanding of macroevolutionary processes.

7-2 FENG, J; SHAHROKHIAN, A; KING, H*; University of Akron; *hking@uakron.edu*

Aerodynamic role of bumps on fog baskers

Namib desert beetles with bumpy elytra have been frequently cited as a source of biological inspiration in the context of harvesting fog for fresh water. The narrative typically portrays the bumps as an adaptation to modify wettability in order to facilitate transport of accumulated water to the mouth. The accumulation step, by contrast, depends not on wettability, but fluid dynamics: competition between inertia and drag of suspended liquid droplets (fog) leads to their collision with a target (fog-harvesting organism) placed in their path. While crude geometry partially dictates this accumulation efficiency, we show in careful experiments with simplified analogs that small modification of surface morphology (eg. addition of millimetric bumps) can play a dominant role, reaching a nearly five-fold difference when compared with smooth surfaces of identical wettability. The result suggests an alternative driver of morphological adaptation in animals and plants which depend on direct interception of fog for water.

139-1 FENG, J*; CHOMICKI, G; KING, H; University of Akron, Oxford University; *hking@uakron.edu*

Wind-powered Cooling in Specialized Fijian Ant-plant

Squamellaria are myrmecophytic epiphytes endemic to the islands of Fiji. A clade of six species of *Squamellaria* form an obligate farming symbiosis with a single ant species (*Philidris nagasau*), while three further basal *Squamellaria* species form non-farming facultative symbioses with generalist ants. Here we present the results of an experimental investigation comparing the thermal regulation properties of the ant-farmed and the non-farmed species of *Squamellaria*. Through continuous monitoring of the internal temperatures of the ant-plants, we observed that the ant-farmed *Squamellaria* (*S. imberbis*) can efficiently harness external wind for cooling its internal domatia, while their non-farmed relatives (*S. wilkinsonii*) do not harness wind. This observation is consistent with the differences between the two types of *Squamellaria* in internal connectivity and entrance holes distribution. Specifically, the ant-farmed *Squamellaria* have interconnected domatia and have entrance holes all around their external surfaces, while the non-farmed species have domatia with distinct cavities and have entrance holes almost exclusively at their base. Ant-farmed *Squamellaria* have lower thermal mass than non-farmed *Squamellaria* of similar sizes, thus their ability to utilize wind for convective cooling may be of crucial importance to their survival.

44-2 FENNER, JL*; COUNTERMAN, BA; Mississippi State University; *Jls1393@msstate.edu*

A Tale of Two Colors: How Structural and Pigmented Wing Colors Share a Developmental Mechanism in the Seasonally Polyphenetic Southern Dogface Butterfly

The vast array of biodiversity and natural variation that we see around us has been generated through a combination of genetic and environmental influences. Butterfly wing coloration provides an attractive evolutionary model to study the role of these interactions throughout development. Here we have I.) Characterized the developmental plasticity of pigment (pink) and structural (Ultraviolet) butterfly wing colors, II.) Investigated the environmental triggers responsible for both colors, III.) Examined a potential ecological significance of the pink polyphenism and IV.) Tested a candidate gene from the melanin pathway generating the polyphenetic variation. Through collections we demonstrate the seasonal polyphenism in both pterin pigmentation and UV structural coloration on *Zerene cesonia* wings. Our results show that both photoperiod and temperature are necessary for the induction of both color changes, but the threshold for the change to pink is sexually dimorphic. Characterizations revealed scale level organizational and morphological changes throughout the pink morphs. We have evidence suggesting that the pink coloration may be caused by an increase in melanin, which is supported by thermal measurements showing that winter morphs warm faster than summer morphs. Lastly, we show, using CRISPR/ cas9, that knockouts of the eyespot melanin gene *Spalt* can partially induce the pink phenotype when grown in summer conditions. *Spalt* knockouts recapitulate the pink phenotype in both pigment and morphological changes. Overall this work suggests that there may be a shared environmental and developmental mechanism between pigment and structural coloration in the Southern Dogface Butterfly

P2-268 FENNER, JL*; CONCHA, C; COUNTERMAN, BA; MCMILLAN, W; Mississippi State University, Smithsonian Tropical Research Institute; *Jls1393@msstate.edu*

Does the Wnt pathway Modulate Pigment and Structural Variation on Butterfly Wings?

Animal coloration is an attractive model for studying how conserved developmental toolkit genes influence the form and function of traits. Butterfly wing patterns provide an ideal system for studying how highly conserved developmental genes are responsible for generating a vast array of natural variation. Recently, it was shown that genes in the melanin pathway modulated both scale color and morphology. Here we examine if a gene, *WntA*, which is responsible for pre-patterning of melanic pigment coloration in *Heliconius* butterflies, also controls cyto-structural variation in wing scales. Knockouts of *WntA* across several *Heliconius* species generated the expected pigment changes, with wing regions typically colored black, instead developing red scales. Here, we show that *WntA* knockouts also had changes in scale structures. The mutant scales were structurally intermediate between wild type black and red scales: the scale ultrastructures (width, length, and area) were similar to black wild type scales, but the nanostructures (lamella ridge and crossrib distance) were more similar to wild type red scales. Our results suggests that *WntA* is not only responsible for pre-patterning scale pigmentation, but also involved in patterning of scale nanostructures.

33-4 FEO, TJ*; SARANATHAN, V; PRUM, RO; Smithsonian, Yale-NUS College, Yale University; *feot@si.edu*

The bizarre occipital feathers of the King of Saxony Bird of Paradise (Pteridophora alberti)

In recent years, there has been considerable progress in our understanding of the evolution and development of feathers. A wealth of newly described feathered Mesozoic taxa has revealed a long evolutionary history of feather diversity that predates modern birds and research on feather development has begun to uncover the processes that control the shape and color of feathers. In order to draw the most robust interpretations, these productive lines of research rely on detailed descriptions of extant feather diversity. However, many of the most extreme examples of feathers remain poorly described in the literature. The King of Saxony Bird of Paradise (Paradiseaidae: Pteridophora alberti) sports the most bizarre feather known in nature. Adult males have two extremely elongated occipital plumes with a series of square, enamel-blue flags running along one side. Both the shape and color of these feathers is so unusual that the first specimens brought to England were confidently declared a fake by leading ornithologists. Here, we use a combination of TEM, SEM, SAXS, and high-resolution synchrotron CT to give the first detailed descriptions of the morphology, structure, and color of the bizarre Pteridophora occipital plumes.

40-4 FERGUSON, SM*; BARR, JI; BATEMAN, PW; Kalamazoo College, Curtin University; *stephen.ferguson@kzoo.edu*

Silver gull flight initiation distance varies with human predictability, not habituation

Animals must make escape decisions based on the perceived risk presented by potential predators. In populated environments flight initiation distance (FID) from approaching humans is often shorter, likely due to habituation to human presence. We asked whether birds are able to discriminate between human approaches in different contexts and adjust their FID accordingly. Penguin Island is a small island off the coast of Western Australia. Access to the island is common and frequent, with multiple daily ferry trips; however, human activity varies across three distinct environments: a boardwalk, beaches, and a native scrub wildlife sanctuary. We tested the FID of silver gulls (*Chroicocephalus novaehollandiae*) across each habitat, predicting the shortest FID on the boardwalk, where human approaches are frequent and follow a predictable path, intermediate FID on the beach, where human approaches are frequent but follow unpredictable paths, and longest FID in the scrub, where human approaches are infrequent and follow unpredictable paths. We found that FID was shortest on the boardwalk, but did not differ between the beach and scrub. In addition, distance from the boardwalk did not affect FID in the scrub. We suggest that silver gulls use human path predictability in specific contexts, rather than habituation to human presence alone, as a primary factor in making escape decisions.

P2-185 FERGUSON, QR; TOGLIA, DS; MCCARTAN, RJ; LEININGER, EC*; New College of Florida; *eleininger@ncf.edu*

Characterization of X. muelleri laryngeal muscle fiber type using ATPase histochemistry: behavioral and evolutionary implications

Xenopus is an excellent system for investigating how structure and function of peripheral effectors can shape behavior outputs in species- and sex- specific fashions. Most *Xenopus* species produce vocalizations that are sexually dimorphic in temporal structure and inter-pulse interval (IPIs); male call IPIs are typically shorter than female call IPIs, or female calls are absent altogether. In most species investigated, laryngeal muscle fiber type is sexually dimorphic and supports vocal sex differences; male laryngeal muscle is composed of fast twitch fibers, while female laryngeal muscle contains both fast and slow twitch fibers. A subset of *Xenopus* species including *X. borealis* and *X. muelleri* have reduced vocal sex differences; IPIs do not differ between sexes, and are longer than those of other species. We have shown previously that *X. borealis* laryngeal muscle contains fast and slow twitch fibers in both sexes, suggesting that the sexually differentiated laryngeal muscle fiber type characteristic of other species has been lost in *X. borealis*. In this study, we asked whether loss of a sexually differentiated fiber type is unique to *X. borealis* or shared with *X. muelleri*, a closely related species with reduced vocal sex differences. General laryngeal features, such as mass, is sexually dimorphic in *X. muelleri*. ATPase histochemistry under acidic preincubation conditions suggest a mixture of acid-sensitive and acid-stable fibers in male and female laryngeal muscle (indicating a mixed twitch type). Our present findings suggest that evolutionary loss of a sexually differentiated fiber type may be common to species closely related to *X. borealis*.

20-1 FERNANDES, JS; St. Petersburg College, Tarpon Springs;
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Nature is the Classroom

Students rarely have the opportunity to experience what they learn in the classroom. Unfortunately, this may lead to apathy for environmental science and conservation. I teach a course called Field Biology of Florida, that is required for environmental science majors and can be taken to fulfill a science requirement for non-majors. Instead of a typical lecture in the classroom, students go out into the field and receive information about the habitat as they come across it in nature. Through strategic partnerships with local parks, state parks, national parks, non-profits and industry, I am able to take students to different locations every week. The last trip of the semester is a 3-day trip to the keys to swim in the national marine sanctuary and visit the sea turtle hospital. In this way, students experience nature and learn the importance of environmental conservation. The final day of the class has student groups present on the field trips experienced during the semester. This serves as a way to reinforce and review material before students take the comprehensive final at the end of the day. The best part of the class, is seeing someone who has not cared about the environment previously, use a reusable water bottle or refuse a straw at a restaurant. Offering more courses like this may create scientists and non-scientists that are passionate preserving our world.

60-6 FERRIS, KG*; COOP, GM; SCHMITT, J; Tulane University, Univ. of California, Davis; *kferris@tulane.edu*

Genetics of Parallel Leaf Shape Evolution in the Mimulus guttatus Species Complex

Parallel evolution, or the independent evolution of similar phenotypes in organisms occupying similar environments, is strong evidence of adaptation. Whether convergent phenotypes are controlled by the same genetic loci and mutations, and therefore whether evolution is predictable at the molecular level, is a central question in evolutionary biology. To address this question we examine the genetic and adaptive significance of parallel leaf shape evolution across and within species in the Mimulus guttatus species complex. Lobed and narrow leaves have evolved from the entire, round leaves of M. guttatus in M. laciniatus, M. nudatus, and a polymorphic serpentine M. guttatus population. In addition to having divergent leaf shapes, all three of these taxa occur in harsh rocky habitats. We used (1) population genetics to detect local adaptation in leaf shape across altitudinal clines of M. laciniatus, (2) phenotypic selection analysis to test whether lobed leaf shape is adaptive in M. laciniatus' granite habitat, and (3) quantitative trait locus (QTL) mapping and genome wide association to examine whether leaf shape evolution has a parallel genetic basis across three rocky outcrop Mimulus taxa. We found that (1) leaf lobing appears to be adaptive at high elevations across multiple altitudinal clines in M. laciniatus, (2) leaf shape is adaptive in rocky outcrops, and (3) leaf shape is controlled by overlapping genetic regions in all three Mimulus species. This overlap in QTL's and harsh rocky habitats suggests that parallel genetic evolution is responsible for adaptive leaf shape evolution across Mimulus.

60-8 FETCHER, N*; PARKER, TC; MCGRAW, JB; MOODY, ML; STUNZ, E; CURASI, SR; TANG, J; Wilkes University, University of Stirling, West Virginia University, University of Texas, El Paso, University of Notre Dame, Marine Biological Laboratory;
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Local Adaptation and Adaptive Lag in an Arctic Sedge, Eriophorum vaginatum

Populations that are adapted to local conditions may lose fitness as climate changes. This phenomenon, called adaptive lag, is potentially significant for Arctic ecosystems where the climate is warming rapidly and locally adapted populations occupy large areas. *Eriophorum vaginatum* is a tussock-forming sedge that occupies more than 300 million km2 in northern Alaska, Canada, and Siberia, where it contributes up to 37% of primary productivity and forms the undulating structure of tussock tundra. A 31- year reciprocal transplant experiment with *E. vaginatum* in Alaska showed that mass/tiller and flowering exhibited local adaptation, whereas survival and the growth rates of tiller populations displayed adaptive lag. Analysis of population genomic data using ddRAD sequencing showed significant differentiation between populations of *E. vaginatum* north and south of the tree line. In a common garden, northern populations senesced earlier than southern populations. In a second experiment established in 2014, gross primary productivity of tussocks from warmer southern sites was more sensitive to transplanting than that of tussocks from northern sites, which suggests that ecotypic control of GPP may affect the response of ecosystem productivity to climate change. As the climate warms, gene flow from south to north is likely to be limited for this long-lived species, and the probability of evolutionary rescue is not great. Instead, the abundance of *E. vaginatum* may decline followed by its replacement by shrubs. Because of the important role of this species in the Arctic tundra ecosystem, patterns of primary productivity and nutrient cycling are also likely to change.

45-2 FIEDLER, K; COOPER, WJ*; Washington State Univ.;
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An automated method for collecting biomechanical data from high-speed videos of fish feeding

Functional morphologists commonly utilize high-speed video to record movement and then use these recordings to measure aspects of biomechanical performance. Methods that rely upon measurements taken from individual video frames typically require extensive processing time, which in turn limits the amount of data that can be feasibly collected. Many kinematic studies have been restricted to small sample sizes that limit the application of statistical analyses. Although collaborative teams of researchers can process larger amounts of video in a given length of time, different members of the same research group will frequently extract different measurements from the same recording. Observer bias is therefore another serious issue that undermines the statistical integrity of kinematic studies. Automated methods can significantly reduce the time required to extract biomechanical measurements from video recordings. This not only supports the collection of larger datasets, and therefore a more rigorous application of statistical analyses, but also eliminates errors introduced through observer bias. Here we discuss an automated technique for extracting performance data from high-speed videos of fish feeding. This method collects measurements of velocity, acceleration, gape distance, jaw protrusion distance, hyoid depression distance, cranial elevation angle, and a ram-suction index estimate for individual video recordings of fish feeding strikes. These measurements are widely utilized by a number of labs investigating the functional morphology of fish feeding.

S2-2 FIELD, KA*; LILLEY, TM; OGATA, G; ROGERS, EJ; PROKKOLA, JM; MOORE, MS; REEDER, DM; Bucknell University; *kfield@bucknell.edu*

The Challenges of Transcriptome-wide Comparisons Across Species and Genera

Comparing host responses to infection between individuals at the whole-transcriptome level has provided valuable insights into the mechanisms of disease resistance and susceptibility. To determine the ecological-scale responses that control disease ecology, it would be helpful to compare transcriptome-wide gene expression changes between species. However, comparisons across species and genera that are not closely related present challenges that can bias the conclusions generated. We have compared the response to white-nose syndrome (WNS) in two North American species of bat that differ in their susceptibility to the fungal pathogen *Pseudogymnoascus destructans*. The WNS-susceptible species, *Myotis lucifugus*, has been shown to respond to infection by activating inflammatory immune responses, among other pathways. To compare responses in a species of bat that is relatively resistant to infection, we measured gene expression using RNA-Seq in *Eptesicus fuscus*. We compared several pipelines to determine the best approach for comparing gene expression between genera and found that using orthologs defined by BLAST homology was the most conservative. This approach will allow the most direct comparison of functional differences in gene expression patterns. To be effective for comparisons between distantly related species, either large numbers of biological replicates or paired sampling will be needed for differential expression analyses.

95-2 FINCH , G.; PERRETTA, C.; DAVIES, B.; ROSENDALE, A. J.; HOLMES , C. J. ; JENNINGS, E. C.; GANTZ , J. D. ; SPACHT, D. ; LEE JR., R. E.; DENLINGER, D. L.; WEIRAUCH, M. T. ; BENOIT , J. B. *; University of Cincinnati, University of Cincinnati , Miami University, The Ohio State University, The Ohio State University , Cincinnati Children's Hospital Medical Center ; *joshua.benoit@uc.edu*

RNA-Seq and Proteomics Analyses of Mechanisms Underlying Reproduction in the Antarctic Extremophile, Belgica antarctica

The Antarctic midge, *Belgica antarctica*, is a wingless fly endemic to Antarctica. The life cycle of this midge is unusually long due to the short periods in which conditions for growth and development are favorable. The larval stage lasts for two years, and the adult stage is brief at about two weeks; adults mate in swarms, and females die shortly after oviposition. Eggs are laid suspended in a gel of unknown composition that is generated by the accessory glands. Reproduction in *B. antarctica* and other midge species is not well understood. This project examined molecular mechanisms underlying reproduction in *B. antarctica* by assessing differential gene expression in males, females, and larvae, as well as male and female accessory glands. In males, females, and larvae, 392, 1825, and 862 uniquely up-regulated genes were identified, respectively. For the accessory glands, 20 and 25 genes were enriched from the females and males, respectively. Proteomic analyses were used to establish the composition of the egg-containing gel, which was followed by RNA-seq analyses to determine the source of the proteins comprising the egg gel. Lastly, thermal and dehydration assays on the egg-containing gel reveal that it likely acts as a buffer to prevent thermal stress of the eggs. Future studies may focus on the impact of climate change on the survivability of this Antarctic species as reproductive shifts or suppression can result in rapid population declines.

P3-107 FINGER, JW*; HAMILTON, MT; KELLEY, MD; ZHANG, Y; KAVAZIS, A; GLENN, TC; TUBERVILLE, TD; Auburn University, University of Georgia; *johnwilsonfinger@gmail.com*

Selenium exposure and its effects on oxidative status in the American alligator (Alligator mississippiensis)

Selenium (Se) is an essential nutrient, which in excess can cause toxicity. Anthropogenic activities, such as the disposal of coal combustion waste products, are increasing the risk of Se exposure worldwide. However, most research investigating the toxic effects of Se have been limited to organisms of lower trophic status or organisms that are shorter lived. To counteract this, we administered juvenile American alligators (*Alligator mississippiensis*) 1000 or 2000 ppm selenomethionine (SeMet) or control water for 7 weeks. After this 7-week period, all alligators were euthanized and tissues were stored -80°C until analysis. Levels of superoxide-dismutase-1 (SOD1), SOD2, and glutathione peroxidase-1 (GPX-1) were measured in whole blood and tail muscle by Western blotting. Save for blood SOD2 levels ($p < 0.01$), SeMet treatment did not affect any other parameter investigated ($p < 0.05$). As this is the first study to investigate Se exposure and its effects on oxidative status in crocodilians, future studies are warranted.

P2-149 FINKLER, MS; Indiana Univ. Kokomo; *mfinkler@iuk.edu*

Fluctuating temperature during incubation triggers differential embryonic growth and development during the organogenesis phase of embryogenesis in Chelydra serpentina.

Diurnal fluctuations in nest temperature have been shown to affect incubation duration as well as the sex, physiological performance, and size of hatchling turtles. The influence of temperature fluctuation on embryonic growth and development rates at different developmental phases, however, is not well understood. In this experiment, I incubated Snapping Turtle (*Chelydra serpentina*) eggs at either "constant" (25 ± 0.5 °C) or "fluctuating" (12 h at 29 ± 0.5 °C, 12 h at 21 ± 0.5 °C) thermal conditions. I sampled embryos at predicted time intervals for the onset of organogenesis (Yntema stage 10), the onset of early growth (YS 14), and the onset of late growth (YS 19) as well as at hatching. Embryo dry mass and development stage did not differ between the two groups early in the organogenesis phase, but by the onset early growth phase embryos in the fluctuating thermal treatment had significantly higher dry masses (~42% greater) and were more developed (by ~1 Yntema stage) than those in the constant thermal treatment. The proportional size and developmental difference observed at the beginning of the early growth phase persisted into the beginning of the late growth phase. However, there was no significant difference in incubation duration, in hatchling dry mass, or in various linear measurements of hatchling size between the two treatments. These findings suggest that the organogenesis phase of development is particularly sensitive to diurnal fluctuations in temperature with respect to both growth and development. Overall growth during the late growth stage of embryogenesis, however, appears to be largely determined by the overall size of the egg and the resources contained within, resulting in little difference in hatchling size as a result of fluctuating incubation temperature.

97-4 FINTON, CJ*; OPHIR, AG; Cornell University; *cjf225@cornell.edu*
Is spatial memory impacted by intranasal administration of oxytocin or vasopressin? Chronic intranasal vasopressin influences spatial memory in male prairie voles
Oxytocin (OT) and vasopressin (VP) are known to modulate pairbonding, but are less appreciated for their influence on cognition, including spatial memory. While pairbonding is a key feature of monogamous mating tactics, the ability to track conspecifics in space lays the foundation for mating decisions. OT and VP represent a mechanistic link between mating tactics and space use. To examine how nonapeptides impact spatial memory, we manipulated exogenous OT and VP in prairie voles through acute or chronic doses. Prairie voles are socially monogamous rodents that demonstrate individual variation in decisions to form bonds and mate monogamously, and are a good species to ask how nonapeptides influence memory to impact mating decisions. Acute doses were administered to adults 30 min before memory testing; chronic doses were administered during post-natal development (PND 21-45 daily) and subjects were tested as adults. OT or VP was delivered intranasally to minimize invasiveness. Spatial memory was tested in the Morris water maze. Chronic VP treatment improved spatial memory compared to controls. We detected no effects of chronic OT, or acute OT or VP on spatial memory. Although VP and OT are known to impact various forms of memory, acute doses did not alter spatial memory. The organizational effects from chronic VP during development appeared to impact spatial memory. Whether the VP system itself was responsible for this memory improvement remains an open question. These data suggest that therapeutic uses of nonapeptides should be considered with caution. Ultimately, we hypothesize that individual variation in circulating VP might impact spatial memory, which may have cascading effects on mating tactics demonstrated by adults in natural contexts.

80-3 FISH, FE*; NICASTRO, AJ; ST. LEGER, J; West Chester Univ., Sea World; *ffish@wcupa.edu*
Spin-leap Performance by Cetaceans Is Influenced by Moment of Inertia
Cetaceans are capable of extraordinary locomotor behaviors both in water and air. Whales and dolphins can execute aerial leaps by swimming rapidly to the surface of the water to achieve an escape velocity. Previous research on spinner dolphins demonstrated that this species was capable of leaping and completing multiple spins around their longitudinal axis with high angular velocities. This prior research suggested that the slender body morphology of spinner dolphins allowed for rapid spins in the air. The principals factors affecting the number of aerial spins a cetacean can execute are the moment of inertia of an individual and the use of control surfaces for subsurface corkscrewing, both of which are morphology-dependent. For typical individual spinner dolphins, Pacific striped dolphins, bottlenose dolphins, and humpback whales, each with swim speeds of 6 m/s, a speed close to their maximum, our model predicts that the number of aerial spins executable are 7, 2, 1.7, and 1.4, respectively, which are consistent with observations. These data imply that the rate of subsurface corkscrewing is limited to 2.7 rev/s for spinner dolphins, 2.0 for striped dolphins, and less than 1 rev/s for the bottlenose dolphins and humpback whales. The greater moments of inertia for the latter three species produce large torques on control surfaces that limit subsurface corkscrewing motion and aerial maneuvers.

P2-55 FJORDBOTTEN, KM*; BRINKMAN, BE; IWANIUK, AN; Univ. of Lethbridge, Alberta; *krista.fjordbotten@uleth.ca*
Sexual Dimorphism in the Morphology of Neurons in the Prefrontal Cortex of Richardson's Ground Squirrels
Sexually dimorphic behavior is often correlated with variation in relative and absolute sizes of brain regions. However, few studies have tested whether this also extends to neuronal morphology within brain regions of wild species. Richardson's ground squirrels (*Urocitellus richardsonii*) exhibit sexually dimorphic social behavior; females being far more tolerant of other individuals and less aggressive than males. Because the prefrontal cortex plays a key role in modulating social behavior, we hypothesized that the neuronal morphology within the prefrontal cortex is sexually dimorphic in Richardson's ground squirrels. We used virtual microscopy to image Golgi stained pyramidal neurons within the medial prefrontal (mPFC) and orbitofrontal (OFC) cortices of wild caught male and female ground squirrels. From these images, we traced over 180 neurons across both regions and quantified 17 different measurements of neuronal morphology. Mixed models revealed that soma and total neuron volumes are significantly larger in males than females within the OFC. Convex hull and basal dendritic volumes are also significantly larger in males than females in the mPFC. Thus, males tend to have larger neurons with broader dendritic trees, despite a female bias in mPFC volume. Males are larger than females, so these sex differences in neuronal morphology likely reflect larger male brains rather than sexually dimorphic behavior. We suggest that other variables might be more closely associated with sexual dimorphism in Richardson's ground squirrel social behavior, such as dendritic spine density or nonapeptide receptor distribution.

31-4 FLAMMANG, BE*; COHEN, KE; HERNANDEZ, LP; New Jersey Institute of Technology, University of Washington, George Washington University; *flammang@njit.edu*
Sucker with a Fat Lip: Functional Morphology of the Soft Tissues of the Remora Adhesive Disc
Remoras comprise a family of fishes (Echineidae) unique in their cranial adhesive disc evolved from dorsal fin spines. Analysis of the adhesive mechanism by which remoras attach to hosts of varied roughness has focused primarily on the functional morphology of skeletal structures; little attention has been paid to the soft tissues of the disc and their role in attachment. Here, we use scanning electron microscopy (SEM), histology, and material testing to describe the functional morphology of the soft tissues of the remora adhesive disc and generate hypotheses on their roles in the adhesive mechanism. Using SEM we identified previously undescribed papillary structures on the fleshy lip surrounding the disc and found epithelial tearing on the lamellae suggestive of spinule replacement and growth Histological examination revealed complex arrangements of collagen fibers with more dense and organized collagen bundles found anteriorly. Moreover, collagen bundles at the anterior lip were oriented in a cross-hatching pattern, suggesting a functional regionalization between the anterior and posterior sections of the lip. Histology did not show any mucus or mucus secreting cells; however, it did reveal large nerves extending down the distal edges of the lips and at times reaching the individual papilla, indicative of a role in modulating attachment forces.

124-2 FLANIGAN, KAS*; WIEGMANN, DD; BINGMAN, VP; Bowling Green State University ; *kflani@bgsu.edu*

Tactile cues facilitate shelter discrimination in Amblypygi (Arthropoda: Arachnida)

Amblypygi are a nocturnal order of arachnids that live in tropical and subtropical regions. These animals have specialized appendages-antenniform legs-that process olfactory, mechanosensory, and chemosensory cues. These sense organs are used by amblypygids to relocate and recognize a home site after a night of foraging. Olfaction appears to play a key role in their ability to navigate successfully. The purpose of this experiment was to determine whether tactile cues might also be involved. Amblypygids can discriminate two different tactile stimuli by associating a viable shelter and an inaccessible shelter with randomly assigned tactile stimuli. Animals were allowed to wander freely in an arena that contained an accessible and inaccessible shelter, where the two shelters were cued by distinct tactile stimuli. They were then tested in a small arena with a floor that was divided into two sections, equally covered by each tactile stimulus. Preference scores based on occupancy in the two sections of the test arena suggest that subjects learned to associate tactile cues with access to a shelter.

P3-26 FLEISSNER, E.R.*; MENSINGER, M.E.; University of Minnesota Duluth, Truman State University; *fleis133@d.umn.edu*

Kinematics of the Flying Carp

In the 1980's, invasive silver carp (Hypophthalmichthys molitrix) escaped from captivity within the United States and spread throughout the Mississippi River Drainage. Silver carp are planktivorous fish that severely disrupt ecosystems by competing with native filter feeders and altering the composition of the lowest trophic levels. They have gained additional notoriety due to their prodigious jumping behavior in response to moving watercraft, which field studies have shown can be induced by both water turbulence and sound. The triggering mechanism and the functional significance of the jumping behavior remain unknown. To better understand the behavior, 5 silver carp were filmed with a high speed camera mounted below an aquarium and stimulus latency, tail amplitude, tail frequency and swim velocity were monitored during jumping following a mechanical stimulus. The jumping behavior consistently followed a startle response, in which the peak amplitude of tail beats increased from roughly 1.28 cm during normal swimming to 1.60 cm and tail beat frequency increased threefold to 10 - 20 beats/second. Since results suggest jumping is initiated after the startle response, Mauthner neurons may be mediating the response.

P3-163 FLOCK, TM*; KRAMER, AM; LAJEUNESSE, MJ; University of South Florida; *tflock@mail.usf.edu*

The Cost of Trait-Mediated Interactions and Indirect Effects within Predator-Prey Dynamics

Predators shape food-web dynamics and ecosystem interactions in two ways. First by consuming prey, which removes individuals from populations and has positive effects on predator birth and survival. This is known as the density-mediated effect of predators on prey. Secondly, predators affect biotic interactions and food-web dynamics via nonconsumptive, trait-mediated effects. This occurs when predators and the risk they pose change the behavior, morphology, or physiology of prey. Trait-mediated interactions (TMIs) have been reported for a broad group of taxa, and early meta-analyses of these studies concluded that TMIs affect prey population dynamics as strongly as density-mediated interactions (DMIs). However, there has since been considerable growth in research on TMIs and DMIs, as well as new research synthesis standards and practices that can help provide new insight on the impact of direct and indirect effects of predators. Here we describe a phylogenetic meta-analysis that first tests whether DMIs are more or less influential at shaping prey populations than TMIs, and then examine the TMIs caused by invasive species. Invasive species are projected to increase over time and a better understanding of key trait-mediated interactions of invasive species is needed. Our synthesis contained mostly papers published after 2005 (532/664 papers that were relevant to the literature search were published after 2005), and we hypothesized that TMIs have similar effects as DMIs on shaping prey populations due to the cost of the tradeoffs imposed on prey species under nonlethal predator exposure. This meta-analysis updates and strengthens our understanding of biotic interactions and consumer-resource dynamics, and helps predict which invasive species traits are most detrimental to native species via TMIs and indirect effects.

5-3 FLORES, DV*; JANZEN, FJ; Iowa State University; *dvflores@iastate.edu*

Epigenetic variation in a reptile: implications for temperature-dependent sex determination

Vertebrates with temperature-dependent sex determination (TSD), a mechanism that relies on incubation temperature to irreversibly determine the sex of developing embryos, are threatened by ongoing changes in climate and local environmental conditions. Previous studies have suggested that behavioral and molecular plasticity in this system may provide opportunities for species with TSD to adapt to these changes. Although decades of research have uncovered key aspects, a complete molecular mechanism of TSD remains elusive. DNA methylation is a well-known epigenetic mark characterized by its dynamic ability to silence genes, and evidence is accumulating for its role in determining sex in TSD systems. Using the painted turtle, *Chrysemys picta*, as a model for TSD, we examined epigenetic profiles, variation, and their implications for sex determination in the TSD system. We leveraged a long-term study site to assess sex-specific epigenetic profiles across the genome and environmentally-induced epigenetic variation. We found clear sex-specific DNA methylation profiles, with adult males exhibiting higher levels of methylation than adult females. We also saw DNA methylation decrease with age, regardless of sex. Additional epigenetic variation was induced by environmental factors, including incubation temperature and embryonic exposure to endocrine disrupting compounds. We then assessed the biological significance of these findings in the context of inheritance by comparing epigenetic profiles between adult females and their offspring. Inheritance of epigenetic variation has the potential to mediate the effects of environmental change on species with TSD, as the methylation composition of genes in the sex determining pathway may play a role in gonadal sex differentiation and ultimately influence the final sex of the individual.

P1-9 FLORES, DV; STRICKLAND, JT; BODENSTEINER, BL; JANZEN, FJ*; Iowa State University, U.S. Fish and Wildlife Service, Virginia Tech University; *fjanzen@iastate.edu*

Planting an Outreach TREE: Exposing Diverse Students to Ecological Research with Reptiles

Women and minorities are seriously underrepresented across the sciences. To help create positive change in ecology, we developed a program called TREE (Turtle Camp Research and Education in Ecology). We seeded the program primarily with an economically and racially diverse group of high school students from rural and urban areas, along with undergraduate and graduate student mentors from across the United States. Participants converged at a field site in northwest Illinois on the Upper Mississippi River National Wildlife and Fish Refuge and the Army Corps of Engineers Thomson Causeway Recreation Area during June of 2007-2012 and 2014-2018 (totaling 59 different high school students, 28 undergraduate students, 17 graduate students, and 4 post-doctorates over the 11 program years). All individuals worked toward four main goals at the site: research experience, education, local outreach, and mentoring. The program capitalized on the extensive diversity of reptiles at the site, giving the students hands-on experience with research and related activities. Anonymous surveys of the high school participants - the vast majority of whom were women and/or racial minorities - revealed that TREE provided an excellent environment for advancing interest in, and knowledge of, science and for influencing career plans of the participants. Many alums have since pursued science-related degrees at universities. This program is a successful model of the importance of outreach, and near-peer mentoring in diversifying the STEM workforce. We thus hope that TREE inspires other research groups to develop programs to expose students from diverse backgrounds to ecological research, education, outreach, and mentoring

26-1 FLOREY, CL*; MOORE, PA; Bowling Green State University; University of Michigan Biological Station; *cflorey@bgsu.edu*

Comparison of Burrow Structure Between Crayfish Species

Crayfish construct and inhabit burrows for temperature and moisture regulation, predator avoidance, and brood care. Burrow function is closely linked to structure, but the subterranean nature of crayfish burrows has limited the collection of quantitative data on burrow morphometrics. The aim of this study was to investigate what characteristics of burrow structure can be correlated to species and habitat, through phylogenetic and photogrammetric analysis. Populations of *Faxonius rusticus*, *F. propinquus*, *Cambarus diogenes*, *Fallicambarus fodiens*, and *Procambarus acutus acutus* were collected from burrows and data on demographics and individual morphology were collected. Fiberglass casts of burrows were created by filling burrows with polyester resin. Excavated casts were digitized using photogrammetric 3D modeling. Digital models were used to calculate total burrow volume and surface area, as well as volume, surface area, depth, and angle to horizontal of burrow entrances, galleries, branches, and chambers. Principal component analysis and structural equation modeling were used to quantify relationships between crayfish characteristics and burrow structure, with a strong correlation between species and burrow volume, surface area, depth, number of entrances, number of branches, and number of chambers. There was not a significant relationship between soil characteristics and burrow structure.

P3-73 FOLEY, KJ*; MCALISTER, JS; College of the Holy Cross; *kjfole19@g.holycross.edu*

Egg Size, Composition, and Energy in Suspected Hybrid Asterias Seastars

Egg size and composition vary both within and across marine invertebrate taxa. Generally, smaller eggs contain fewer maternally provisioned biochemical constituents for developing larvae, whereas larger eggs may provide more of these materials and energy. Of these constituents, proteins are used primarily for morphogenesis, whereas lipids are used for both metabolism and morphogenesis. Larger eggs do not always correlate with increased maternal provisioning, however. In fact, how egg size, composition, and energy co-vary is not entirely understood. In some cases, larger eggs may have similar constituent amounts as smaller eggs, but greater volumes of seawater or energy-poor carbohydrates. Hybridized individuals of the sea star *Asterias* have been observed to produce two size classes of eggs. Hybrids may show more variation in egg size across reproductive females than within populations of purebred females, but whether this variation is due to differing amounts of biochemical constituents or seawater is unknown. We assayed the eggs of 12 suspected hybrid *Asterias* females collected from within a hybrid zone for protein composition. While none of the females we spawned produced two different size classes of eggs simultaneously, we did find that across females, the eggs we obtained fell into two different size classes: smaller eggs (egg volume <1.1 nL) and larger eggs (egg volume >1.1 nL). Colorimetric assays indicate that the protein amount of smaller eggs was not significantly less than in larger eggs and that protein density decreased as egg size increased. We are conducting additional assays for lipid and carbohydrate composition, which will provide a more complete understanding of maternal investment in the eggs of *Asterias rubens* and *Asterias forbesi* collected from within a hybrid zone.

P2-278 FONTANA, RM*; CHANDLER, CH; SUNY Oswego; *rfontana@oswego.edu*

Identification of transposable elements in the genome of the terrestrial isopod Trachelipus rathkei

Transposable elements are sequences of DNA which appear multiple times throughout a genome. This is because the transposons are able to jump around the genome, often bringing with them sections of surrounding DNA. Many crustaceans, including terrestrial isopods, have large genomes which include ample amounts of transposons within them. In our current research, we aim to identify and characterize the transposable elements in the genome of the terrestrial isopod Trachelipus rathkei. Using RepeatModeler, we are annotating the different types of transposable elements in this species's genome. We are also testing a novel and hopefully high-efficiency approach, using high-frequency kmers identified directly from raw Illumina sequencing data to identify families of repetitive elements. This will provide a foundation for future genomic studies in terrestrial isopods.

44-7 FOQUET, B.*; SONG, H.; Texas a&m University;
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A comparative study of behavioral, morphological, and molecular reaction norms of locust phase polyphenism
Locusts are grasshoppers (Acrididae) that form large migratory swarms or marching bands, and show density-dependent phase polyphenism. This polyphenism consists of two phases, a solitarious and a gregarious phase, which manifest in response to low and high population density, respectively. The two phases differ in several traits, including behavior, morphology, nymphal coloration, physiology and reproduction. Moreover, recent studies have shown clear molecular differences between both phases in two well-studied locust species, *Schistocerca gregaria* and *Locusta migratoria*. From a phylogenetic perspective, locusts are rare among grasshoppers, representing only 19 species out of 6700 species, and they are phylogenetically heterogenous group, which strongly suggests that locust phase polyphenism convergently evolved multiple times. The genus *Schistocerca* contains three swarming locust species and more than 40 non-swarming sedentary species, and its phylogeny is well understood. In this study, we focus on the Central American locust (*S. piceifrons*) and three closely related non-swarming grasshoppers that, together, form a spectrum in the degree of density-dependent phenotypic plasticity. We quantified density-dependent reaction norms in *S. piceifrons* and these three related species at a behavioral, morphological and molecular level by rearing them in isolated and crowded conditions. We establish that the spectrum of density-dependent phenotypic plasticity in this clade does not only extend to the behavioral and morphological level, but also to the molecular level. Further, our transcriptome analysis points towards clear similarities and differences in gene expression patterns among these four species. Finally, we compare and contrast our results in *S. piceifrons* to what is known from other locust species.

8-3 FORD, KL*; DONATELLI, CM; GIBB, AC; ALBERT, JA; SUMMERS, AP; University of Louisiana at Lafayette, Tufts University, Northern Arizona University, University of Washington;
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Scaling with Scales: Analysis of armor and swimming through ontogeny in the Bay Pipefish (Syngnathus leptorhynchus)
Syngnathid fishes provide an unusual opportunity to examine dermal armor development throughout ontogeny and quantify the influences of sex-role reversals on the morphology of teleost fishes. Individuals of the Bay Pipefish, *Syngnathus leptorhynchus* (n=16), were filmed, CT-scanned, and measured to analyze swimming kinematics and dermal armor characteristics. These analyses indicate that individuals do not scale proportionally during ontogenetic growth in terms of body diameter, cross-sectional area of the body, or surface area of dermal armor. Instead, larger individuals have a more slender body shape with a much smaller cross-sectional area than is predicted by an isometric growth model. Further, swimming speed and estimated Reynolds number scales with total length to the power of 1.8 and 2.7, respectively. Thus, juveniles of *S. leptorhynchus* become proportionally faster as they grow in size, and swim at lower Reynolds Numbers than mature individuals. Mature Bay Pipefish adults, regardless of sex, have proportionally larger scales that cover a greater percentage of their body when compared with small juveniles. There are also distinct shape differences in the dermal armor between sexes; these differences are likely related to reproductive roles, because male brooding requires specialized bony structures along the abdomen and tail. In summary, body shape and dermal armor in *S. leptorhynchus* change with size and sex, and these variables likely influence the functional characteristics such as Reynolds number and swimming speed.

104-2 FORD, MP*; KASOJU, VT; GADDAM, MG; SANTHANAKRISHNAN, A; Oklahoma State University;
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Clap and fling of bristled wings with varying solid surface areas
The smallest free-flying insects (body lengths between 0.2 to 1 mm) show a marked preference for wings consisting of a thin solid membrane with long bristles at the margins. Flapping flight of these insects occurs under highly viscous conditions where Reynolds number (Re) is on the order of 10. Obligate use of clap and fling kinematics is also seen in tiny insects such as thrips. Recent evidence has shown that bristled wings can provide drag reduction benefits during clap and fling. However, the biological range of variation in bristled wing geometry in tiny insects remains unclear. In this study, we examined the aerodynamic effects of varying the ratio of solid membrane area (MA) to total area (TA) of the wing. Forewing images of thrips were analyzed from published data and MA/TA was found to range from 14-27%. A dynamically scaled robotic platform was used to test 6 different wing pairs with MA/TA varying from 15% to 100%. Experiments were performed with each wing pair at Re=10, and also at Re=120 that is relevant to larger insects such as the fruit fly. Dimensionless lift and drag forces were measured using strain gauges attached to the wing root. Time-resolved particle image velocimetry was performed at 3 different chordwise planes along the span in order to visualize the leading and trailing edge vortices. With decreasing MA/TA, peak lift and drag coefficients decreased, but the lift to drag ratio increased. The magnitude of circulation about the leading and trailing edges of the wings also decreased with decreasing MA/TA. Leading and trailing edge vortices remained attached throughout the stroke at Re=10, while vortex shedding was observed at Re=120 in wing models with high MA/TA. Our results suggest that clap and fling with bristled wings is more advantageous for Re=10 as compared to Re=120.

P2-264 FORD, NT*; FORD, MP; SAMAEE, M; SANTHANAKRISHNAN, A; Oklahoma State University;
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Effects of varying inter-pleopod spacing to pleopod length ratio in metachronal swimming of crustaceans
Long-tailed crustaceans such as krill and mysids use drag-based metachronal swimming for aquatic locomotion. Pleopod pairs are rhythmically paddled starting from the animal tail to head, such that each pleopod pair is delayed in time relative to the neighboring pair. The ratio of inter-pleopod spacing (G) to pleopod length (L) has been observed to lie within a fairly narrow range of 0.2 to 0.7 in a variety of freely-swimming crustaceans (Murphy et al., Mar Biol 158, 2011). In this study, we examined how varying this G/L ratio from 0.4 to 0.6 impacts metachronal swimming performance. A dynamically scaled robotic model capable of self-propulsion was developed for this study. Physical models of idealized paddle-like pleopods were fabricated from acrylic (four pairs) and outfitted onto the robotic platform. The paddles were programmed to oscillate in tail-to-head metachronal motion with 25% inter-limb phase difference. Thrust generated was measured near the leading edge of the robotic model assembly using strain gauges. Our results showed that time-averaged thrust was slightly augmented with decreasing G/L, but peak thrust increased with increasing G/L ratio. The distance advanced by the self-propelling models under varying G/L will be presented.

66-5 FORSBURG, Z.R.; Texas State Univ.; *frog@txstate.edu*
Artificial light at night alters corticosterone levels in Rana berlandieri larvae
Artificial light at night (ALAN) is artificial light that alters the natural light dark patterns in ecosystems. ALAN can have a suite of effects on community structure and drive evolutionary processes that influences a range of behavioral and physiological traits. Our understanding of possible effects of ALAN on amphibians is lacking and research is warranted as ALAN could contribute to stress and declines of amphibian populations, particularly in urban areas. I tested the hypothesis that exposure to constant light or pulsed light at night (simulating a motion sensor light) would physiologically stress leopard frog tadpoles*Rana berlandieri*. Using a reaction norm approach, I reared tadpoles under a natural light cycle for 7 days (baseline) and then under either constant light or pulsed ALAN for 14 days (light treatment). Using water-borne hormones, I measured corticosterone (CORT), the main amphibian glucocorticoid, release rates on days 7 and 21. Compared to baseline CORT release rates, tadpoles showed significantly higher CORT release rates after 14 days of constant light while tadpoles showed significantly lower CORT release rates after 14 days under pulsed ALAN. These results suggest that short-term exposure to constant or pulsed light at night contribute to stress in tadpoles, albeit differently, with constant light inducing CORT production while pulsed ALAN is downregulating CORT production. Further investigation is needed to explore long-term effects of exposure to ALAN, as long-term exposure may lead to chronic stress or tadpoles may habituate to ALAN, and possible carry over effects, as juvenile growth and survival may be affected by exposure to ALAN in the larval stage. Based on our current findings, mitigation of exposure to ALAN should be considered in management and conservation plans for amphibians.

91-8 FRANCIS, JR, AW; Georgia Southern University; *afrancis@georgiasouthern.edu*
Cephalofoil Hydrodynamics of the Winghead Shark, Eusphyra blochii
Hammerhead sharks (Family Sphyrnidae) are characterized by a distinctive lateral expansion of the head known as a cephalofoil. The winghead shark, *Eusphyra blochii*, is the most ancestral member of this group with a high aspect ratio cephalofoil that is 40-50% of total body length. Computed tomography (CT) scans of a winghead shark were used to generate a computer model for performance testing using computational hydrodynamics. This model was tested at multiple angles of attack (pitch) and yaw to determine the velocities, forces, pressures, lift coefficients (C_L), and drag coefficients (C_D) generated by the winghead's cephalofoil. Positive lift coefficients were identified as starting at an angle of attack of +5° and continuing up to +25°. The coefficient of drag was at its lowest at an angle of attack of +10°. These computer simulations were then evaluated using 3D printed models of the winghead shark cephalofoil submerged in a water tunnel and oriented at selected angles of attack to water flow. Digital particle image velocimetry (DPIV) was used to quantify fluid flow around the cephalofoil. Cross-correlation analyses of fluid flow identified velocity differences above and below the cephalofoil as well as at the end of the cephalofoil. Vorticity was also identified trailing the cephalofoil. While swimming level, the cephalofoil of the winghead shark has a natural angle of attack of about +17.6°. At this angle, there is slightly positive coefficient of lift while the coefficient of drag is near zero. However, as the winghead shark elevates or depresses its head (changing the angle of attack), lift and drag characteristics change in a way that is consistent between computer simulations of hydrodynamics and DPIV measurements of fluid flow.

96-2 FRANK, CL*; DAVIS, AD; HERZOG, C; Fordham University, NY Dept. of Health, NY Dept. of Environmental Conservation; *frank@fordham.edu*
The evolution of a resistance to White-nose Syndrome by a North American bat population
White-nose Syndrome is caused by a cutaneous infection with the fungus *Pseudogymnoascus destructans (Pd)*. It is known to produce hibernation mortality rates of 75 - 98% in 4 bats: *Myotis lucifugus*, *M. septentrionalis*, *M. sodalis*, and *Perimyotis subflavus*. These high mortality rates are observed during the first 1-2 years after the arrival of *P. destructans* at a hibernation site and are caused by a 60% decrease in torpor bout duration, which results in a premature depletion of depot fat prior to spring. Little is known about the long-term effects of this fungus on torpor and mortality, thus we conducted a 9-year study on *M. lucifugus* at 2 of the hibernation sites where *Pd* first appeared in North America. The *M. lucifugus* hibernating at these sites one year after the arrival of *Pd* had: a) a mean torpor bout duration of 7.6 d, b) depleted depot fat reserves by March, and c) a mortality rate of 88-92%. The *M. lucifugus* hibernating at these sites 6-9 years after the arrival of *Pd*, in contrast, had: a) a mean torpor bout duration of 14.7 d, b) depot fat remaining in March, and c) a mortality rate of 50%. The number of *M. lucifugus* hibernating at these sites consistently increased since 2010 and is now 3.0-3.5 times greater than the number remaining after the winter of 2008-09. These findings indicate that this population of *M. lucifugus* has evolved mechanisms to hibernate normally in the presence of *Pd*, thus reducing their over-winter mortality rate.

S11-11 FRANKINO, W. A.*; SHINGLETON, A. W. ; DWORKIN, I.; BAKOTA, E.; WILKINSON, G. S.; WOLF, J. B.; University of Houston, University of Illinois, Chicago, McMaster University, University of Maryland, University of Bath; *frankino@uh.edu*
Individual Cryptic Scaling Relationships and the Evolution of Animal Form
Morphological scaling is central to the expression and evolution of morphology. Scaling relationships fit to populations of individuals describe how overall shape changes with body size, and changes in scaling relationship parameters underlie the generation of much morphological diversity seen within and among biological groups. We take a developmental approach to model the expression and evolution of morphological scaling. Under our model, final trait and body size is a function of their relative sensitivity to changes in access to nutrition during well-defined growth windows. Because individual growth is dependent on access to nutrition, each individual can express a continuum of trait and body sizes. The function that describes these potential trait and body sizes is, in effect, a ‘cryptic' scaling relationship on which the observed phenotype exists as a single point. Importantly, individuals can vary in their sensitivity to nutritional variation, producing differences among individuals in the intercept and slope of their individual cryptic scaling relationships. Our model reveals that the distribution of these individual cryptic scaling relationships can dramatically affect how the population-level scaling relationship responds to selection. Here we present data illustrating individual cryptic scaling relationships from several biological systems, and we use these data to explore our model's predictions of the response to different patterns of selection.

61-2 FREDERICH, B*; AGUILAR-MEDRANO, R; GAJDZIK, L; University of Liège, Liège, CINVESTAV, Mérida; *bruno.frederich@uliege.be*

Generalist Feeding Guilds in Reef Fishes: Macroevolutionary Sink or Future Source of Diversity?

Reef fishes have diversified into thousands of species that fill various types of ecological niches, contributing to the tremendous biodiversity of reef ecosystems. Yet, the dynamics of this diversity remain understudied, especially the evolutionary relation between the different functional traits, which relate to the life strategies and ecosystem roles of organisms. Here, we explore how one functional trait, the feeding habit, impacts the dynamics of species diversification and functional evolution. Using comparative phylogenetic methods in conjunction with taxonomic, trophic and functional datasets, we analyze the functional evolution of two major radiations of reef fishes, the wrasses (Labridae) and the damselfishes (Pomacentridae). We demonstrate that the feeding habit plays a key role in the evolution of the rest of functional diversity. The nature and the diversity of functional roles hosted by fish in reef ecosystems are tightly linked to their feeding attributes. Counter to a simple prediction of ecological opportunism, we found that "generalist" feeding guilds (*i.e.* those composed of species feeding on food sources from the whole bentho-pelagic compartment) do not show higher rates of functional diversification and do not necessarily display higher levels of functional diversity. Furthermore, in contrast to recent macroevolutionary studies on mammals and birds, we highlight that these "generalist" guilds of fishes represent the basis of future diversity and cannot be considered as evolutionary sinks or as "dead-ends". These findings clearly re-define our view on the ecological and evolutionary roles played by generalist feeding guilds.

113-7 FREDERICK, AR*; CATABAY, C; CLEMENTS, KD; GERMAN, DP; Univ. of California, Irvine, Univ. of Auckland; *alyssa.frederick@uci.edu*

Will abalone survive climate change? Comparative digestive physiology and the effect of temperature stress on abalone across the Pacific Ocean

Withering syndrome (WS), a bacterial disease, has led to population declines in all northeastern Pacific abalone species infected and impacts animals more severely during periods of thermal stress. This study aims to determine the mechanistic impacts of WS and heat stress on abalone digestive function by examining gut function in wild red abalone (*H. rufescens*) and comparing their gut function to WS-free New Zealand pāua (*H. iris*). We hypothesized that abalone digestive function is unable to keep pace with increased metabolic demand at the highest temperatures they experience in the wild, thereby making them more vulnerable to heat stress and WS in the face of climate change. We conducted 4-week thermal stress feeding experiments with both species. Red abalone and pāua were divided into 2 temperature regimes, ambient seawater and 6°C above ambient. We measured total organic matter and individual macronutrient (protein, carbohydrate, and lipid) digestibility to determine how thermal stress impacts the animals' ability to extract nutrients and energy from their diet. We also measured metabolic rate (via O_2 consumption) at both temperatures to determine whether the changes in digestive function enable animals to extract enough energy to meet their increased metabolic demand at elevated temperatures. Preliminary results show that metabolic demand is significantly elevated during the thermal stress treatment and that species differ in their digestive efficiencies, but have the reserve capacity to handle the 6°C challenge. This is one of the first detailed studies on abalone digestion, and collaborations with international fishing, aquaculture, and management agencies is enabling this data to be integrated into management.

73-1 FREEMAN, AR*; SHEEHAN, MJ; OPHIR, AG; Cornell University; *arf86@cornell.edu*

Anogenital distance predicts sexual odour preference in African giant pouched rats

Identifying reproductively viable partners may be the most important aspect of searching for a mate. When females vary in their reproductive receptivity, it is incumbent upon males to discriminate among females based on the likelihood of successful copulation and fertilization. We have observed that female African giant pouched rats (*Cricetomys ansorgei*) demonstrate profoundly delayed sexual development, with some adults exhibiting a highly neotenous, fully fused vagina. The lack of vaginal patency presents a tremendous barrier to mating. Based on this unique observation, we tested male preferences towards urine collected from patent and non-patent females. We found that males with longer anogenital distances (AGD; a proximate measure of developmental masculinisation) show differential interest towards patent and non-patent females, preferring patent females. Strikingly, males with short AGDs did not show any differential interest between female odours. Correspondingly, only patent females demonstrated reduced interest in odour from short AGD males; non-patent females did not demonstrate a preference. Our study demonstrates that pouched rats show differential interest in odours closely associated with mate quality, which could help them locate high quality potential mates. We are the first, to our knowledge, to show that the AGD of the evaluator enhances mate preferences and influences their interest evaluation in potential mating partners. We posit that the preference for reproductively available females by masculinised males and the preference for masculinised males by reproductively available females suggests that assortative mating could promote these pairings of proximally-derived traits.

21-6 FRENETTE, BD*; GIDO, KB; TOBLER, M; Kansas State University; *frenette@ksu.edu*

Metabolic Physiology of Minnows Exposed to Stable and Variable Thermal Environments

Laboratory studies of organismal thermal biology often rely on acclimation to constant temperatures to assess physiological or performance responses, yet organisms in their natural environment are exposed temperature variation across spatial and temporal scales. Incorporating thermal variability into tests of organismal responses to temperature might help elucidate how organisms respond to temperature in variable environments. Additionally, metabolic responses under variable thermal conditions may be an important and often overlooked component influencing an organism's fundamental thermal niche. The southern redbelly dace (*Chrosomus erythrogaster*) and the central stoneroller (*Campostoma anomalum*) are two species of functionally-similar minnows that display differences in their realized thermal niches along a stream-size gradient of temperature. To test how exposure to a variable thermal regime affects metabolic physiology, we measured the metabolic rates of dace and stonerollers acclimated to either constant (20°C) or variable (mean = 20°C; range = 17-23°C) temperature conditions. We then used intermittent-flow respirometry to compare standard metabolic rate (SMR), maximum metabolic rate (MMR), and aerobic scope (AS) of dace and stonerollers at 15, 20, and 25°C. We also compared responses between dace and stonerollers to determine if temperature variation contributes to differences in the realized thermal niches of these species. We found that fish acclimated to a variable thermal regime maintained higher overall AS across the range of test temperatures when compared to fish acclimated to constant temperatures, except for the stonerollers at 25°C, where AS did not differ. The AS of both species acclimated to a variable thermal regime was similar at 15 and 25°C, but stonerollers had higher AS at the mean temperature of 20°C.

136-8 FRIEDMAN, ST*; WAINWRIGHT, PC; Univ. of California, Davis; *sarahtfried@gmail.com*

Getting to the bottom of it: Morphological diversification in benthic teleosts

From flattened flounder, to elongate eels, and leg-wielding frogfishes, benthic fishes exhibit a remarkable diversity of body shapes, many of which deviate strongly from the generic streamlined fish profile. Living on or within the benthos may relax the selective pressures incurred by constant midwater movement and promote complex interactions between the body and substrate, resulting in adaptations and body shapes not favored in midwater fishes. Though fishes have radiated into benthic and fossorial habitats numerous times, the phenotypic diversity of benthic fishes has never been systematically explored and compared to midwater taxa. We ask whether a benthic lifestyle results in novel body shapes and if this habitat transition leads to increased rates of morphological diversification. Using the collections at the Smithsonian Museum, we have amassed an unprecedented morphological dataset of linear measurements capturing body shape across roughly 6,000 teleost species. Applying phylogenetically-informed analyses, we show that bottom-dwelling fishes are far more dispersed in morphospace than midwater fishes. We find that benthic living both facilitates the evolution of novel body shapes and dramatically intensifies the rate of body shape evolution. This study highlights a prime example of the potential for habitat colonization to generate widespread morphological innovation and diversification.

S8-6 FRIEDMAN, Nicholas R*; ECONOMO, Evan P; Okinawa Institute of Science and Technology; *nicholas.friedman@oist.jp*

A morphological integration perspective on the evolution of dimorphism among sexes and social castes

Individuals of many species have evolved alternate morphologies, thus enabling individuals to conditionally match behavioral strategies that are favorable for reproductive success. Examples of this phenomenon include sexual dimorphism, alternative reproductive strategies, and social insect castes. Here, we use the concept of morphological integration to examine the extent to which a trait, belonging to two different ant castes or bird sexes, evolves in a correlated fashion. In the case of social insects, we examine an ant genus in which workers have major and minor worker subcastes that perform different behavioral repertoires in and around the nest. In the case of birds, we examine a family of songbirds that exhibits plumage coloration that can differ greatly between males and females, with apparently independent changes in each sex.

5-2 FRYE, BM*; HANKERSON, SJ; TARDIF, SD; SEARS, MW; DIETZ, JM; Clemson University, University of St. Thomas, St. Paul, Southwest National Primate Research Center, University of Maryland, College Park; *bfrye@g.clemson.edu*

Siblings as an ecological constraint? Physical, reproductive, and survival consequences of sibling competition in a cooperatively breeding primate (Leontopithecus rosalia)

Sexual selection theory posits that animals should fiercely compete to reproduce, but in taxa that breed cooperatively, some individuals delay or even forgo reproduction entirely. Though kin selection often is evoked to explain the evolution of this reproductive strategy, other extrinsic factors likely contribute to the maintenance of fitness asymmetries. In many polytocous taxa, siblings constrain each other's reproductive opportunities. The intensity and form of sibling competition, though, may well depend on the sex of the competitors. Using longitudinal records, we investigated how intra- and intersexual competition among siblings impacts body condition, survivorship, and reproduction in a cooperatively breeding primate - the golden lion tamarin (*Leontopithecus rosalia*). Our preliminary results suggest that sibling sex influences some, but not all, phenotypic outcomes in golden lion tamarins. Ultimately, this examination of sex-dependent sibling competition provides insight into the mechanisms mediating phenotypic outcomes as well as the demographic factors selecting for cooperative breeding across broad taxonomic and geographic scales.

41-5 FU, Q*; LI, C; Johns Hopkins University; *fqiyuan1@jhu.edu*

Body compliance helps snakes traverse large step obstacles

Snakes move well in complex 3-D terrain such as mountains and deserts with large step-like obstacles. Our recent study discovered that a generalist kingsnake (Lampropeltis mexicana) uses a partitioned gait to traverse large steps [1]. The snake's body sections towards the head and tail undulate on the horizontal surface to propel and stabilize the animal, while the middle body section cantilevers in the sagittal plane to bridge across the large step. Despite such high degree-of-freedom body deformation, the animal always maintains good contact with the ground. Here, we use robophysical experiments to test the hypothesis that body compliance is critical to maintaining contact with the terrain to maintain traction and stability. We developed a snake robot that can deform its body in both horizontal and sagittal planes, with one-way wheels to mimic anisotropic friction of snake scales, and used an adjustable suspension system to vary body compliance. Using a snake-inspired partitioned gait, the robot traversed a large step as high as 40% its body length. As compared to using a more rigid suspension, when the suspension was more compliant, the robot maintained better contact with the ground (from 81 ± 8 % of the time to 87 ± 5 % of the time) thanks to larger suspension compression (from 1.0 ± 0.3 mm to 2.1 ± 0.6 mm). This increased traversal probability (from 50% to 90%) for high steps (36% and 38% of body length), but with a sacrifice of higher power consumption (from 24.9 ± 1.4 W to 26.4 ± 1.4 W) and more undulation cycles needed to traverse (from 6.02 ± 2.32 to 8.89 ± 5.17) ($P < 0.05$ for all tests, ANCOVA). Our study demonstrated the importance of body compliance for snakes and snake robots to engage and traverse complex 3-D terrain. ([1] See another talk: Gart SW et al., Snakes partition their body to traverse large steps and inspire a snake robot.)

55-4 FUESS, LE*; PALACIO, A; BUTLER, CC; BRANDT, ME; BAKER, AC; MYDLARZ, LD; University of Texas Arlington, University of Miami, University of the Virgin Islands; *lefuess@gmail.com*

Multiple experiments reveal complex relationships between symbiosis, immunity, and the transforming growth factor-beta pathway in a Caribbean coral, Orbicella faveolata

Scelaractinian corals, which form the basis of reef ecoystems, are declining due to stressors like disease. Corals are nutritionally dependent on symbiotic dinofagellates, *Symbiodinium*. Yet to establish and maintain symbiosis symbionts may suppress host immunity via the host's transforming growth factorβ (TGFβ) pathway. To explore the relationship between symbiosis, host immunity and the TGFβ pathway, we conducted two experiments using the coral, *Orbicella faveolata*. First we examined the relationship between the TGFβ pathway and host immune response. Coral cores were pre-treated with exogenous TGFβ, anti-TGFβ, or a vehicle control, followed by an immune challenge. RNAseq analyses revealed few effects of TGFβ pathway manipulation without immune stimulation. In contrast, enhancement of the pathway with exogenous TGFβ resulted in reduction in immune response, whereas inhibition of the pathway preserved the immune response. Next, we used nutrient enrichment to experimentally manipulate symbiont density in coral cores. Gene expression analyses showed a negative effect of symbiont density on host immune gene expression. Comparison of the results from both studies revealed several genes that are affected similarly by TGFβ pathway manipulation and changes in symbiont density, indicating a potential link between TGFβ and symbiosis. Associated negative effects of symbiosis and TGFβ signaling suggest an ecological trade-off: increased symbiont density may provide energetic benefits to the host at the cost of reduced immunity. Further investigation of these relationships will increase understanding of how variation in symbiotic relationships shapes coral disease resistance.

P2-255 FULBRIGHT, MC*; MOON, BR; University of Louisiana at Lafayette; *fulbrightmc@gmail.com*

Bite Performance in Map Turtles (Graptemys species)

Bite force is an important measure of performance that directly relates to an organism's fitness. The forces produced by the jaw muscles limit the types of prey that can be consumed by an individual, and therefore the nutrition and energy available to the individual. Bite forces have been recorded in diverse taxa, yet many interesting examples, such as some profoundly dimorphic species, remain to be studied. We are studying bite performance in map turtles (*Graptemys* species) that vary dramatically in head size. Map turtles exhibit three different trophic morphologies: The males of all species are considered microcephalic (i.e., have small heads), whereas females may be microcephalic, mesocephalic, or megacephalic (having profoundly large heads). The differences in head size are thought to relate to dietary differences, with megacephalic females being capable of durophagy, and microcephalic individuals being limited to feeding on softer prey items such as aquatic insect larvae. We are measuring bite forces in microcephalic map turtles *Graptemys sabinensis* and megacephalic ones *Graptemys pearlensis*. Our preliminary results show that microcephalic individuals generate forces comparable to many turtles that are dietary generalists, whereas megacephalic individuals are capable of producing much higher bite forces, commensurate with those of similarly sized snapping turtles (*Chelydra serpentina*). These results support the hypothesis that megacephalic map turtles can exploit hard prey that most other species of turtles cannot consume. In future research, we plan to quantify the muscle morphology and maximum tetanic bite forces elicited by direct muscle stimulation.

P2-125 FULLER, RG*; GORMALLY, BM; ROMERO, LM; Tufts University; *rory.fuller@tufts.edu*

An attention-occupying feeding mechanism does not affect glucocorticoid secretion in captive house sparrows (Passer domesticus)

Bringing wild animals into captivity is a crucial aspect of studying stress physiology, as many experiments which are impractical in the wild can be easily performed in a lab environment. However, the mere act of capturing and housing these animals in an unnatural environment substantially alters their stress physiology, potentially in ways that may alter the outcomes of experiments. While most labs therefore employ habituation periods to allow the animals to become used to their new state, it is often the case that animals never fully return to their pre-captivity baseline glucocorticoid secretion patterns. Here we explored whether giving captive house sparrows (*Passer domesticus*) their feed by hiding it deep within a simulated artificial lawn would help to mitigate this early stressful period by giving the birds a task with which to occupy their time, one which mimics their normal feeding patterns in the environment from which they were captured. We observed no significant differences between the experimental and control groups in terms of glucocorticoid secretion patterns. We speculate that either the task is insufficiently diverting to reduce stress from captivity, or that the primary sources of captivity stress for this species arise from other environmental sources.

P1-6 FURIMSKY, MM*; BALCZON, JM; Westminster College, Pennsylvania; *furimsmm@westminster.edu*

Designing an International Travel Course for Both Biology and Non-Biology Majors

International travel courses have enriched research and learning experiences for many undergraduate students as they develop an appreciation for the natural world. As part of the curriculum at a small private liberal arts college, courses involving travel to destinations characterized by a rich and unique biodiversity are regularly offered. These courses are open to the entire student body, so the typical knowledge base varies from students with introductory high school biology to those senior biology and environmental science majors months away from entering graduate or professional programs. The challenge to designing this course is to ensure a balanced and engaging experience for all involved. The curriculum for a recent lecture course and travel experience to Ecuador, including Amazonia, the Andes and the Galapagos Islands, will be described.

P1-291 FURR, D.*; KETCHUM, R. N.; REITZEL, A.; IVANINA, A. V.; Univ. of North Carolina, Charlotte; *denise.furr@uncc.edu*
Genetic and Environmental Determinants of Stress Tolerance Among the Eastern Oyster Population
The Eastern oyster *Crassostrea virginica* is an abundant benthic bivalve found throughout the Atlantic coast, including North Carolina. It is a remarkably resilient species found in intertidal and near-shore estuarine ecosystems. The environmental variation between estuarine, intertidal, and subtidal zones are ideal for studying ecological factors that can affect within species variation at local geographic scales. No data are currently available on combined genetic and physiological comparisons of oysters from geographically-close locations or from different habitats within locations to determine how genetic and environmental factors determine resilience in location-specific patterns. We investigated the contribution of genetic and environmental factors in stress tolerance among *C.virginica* subpopulations from 4 different sites: two estuarine, one subtidal, and intertidal. All studied populations were closely related and differ by less than 1% nucleotide diversity at COI. Basal expression of pattern recognition genes in oysters' hemocytes (HCs) (TLR2,TLR3,TLR4 and Mannose Rec 2), as well as humoral and inflammation-related genes (Big defensin, Lysozyme, Complement system protein Cq3, and Tumor Necrosis Factor) showed a high level of divergence among all studied populations. Exposure to environmental hypoxia led to decrease in expression of all studied genes in HCs of oysters, where oysters from estuaries showed significantly elevated expression of TLR2, TLR4, and C3q. Expression of TLR3, TLR4, and Cq3 were elevated in HCs of oysters from intertidal zones under hypoxic conditions. Our results indicate that closely-related NC oysters have different mechanisms of acclimation to their specific habitats and response hypoxia.

37-4 FURZE, ME*; HUGGETT, BA; AUBRECHT, DM; STOLZ, CD; CARBONE, MS; RICHARDSON, AD; Harvard University, Bates College, Northern Arizona University; *mfurze@fas.harvard.edu*
Understanding Nonstructural Carbohydrate Storage and Seasonal Dynamics at the Whole-tree Level
Despite the importance of nonstructural carbohydrates (NSC) for growth and survival in woody plants, we know little about whole-tree NSC storage. The conventional theory of annual NSC reserve dynamics suggests that NSC reserves will increase over the growing season and decrease over the dormant season. We compared storage in five temperate tree species to determine the size and seasonal fluctuation of whole-tree total NSC pools as well as the contribution of individual organs. NSC concentrations in the branches, stemwood, and roots of 24 trees were measured each month over the course of a year. We then scaled up concentrations to the whole-tree and ecosystem levels using allometric equations and forest stand inventory data. While whole-tree total NSC pools followed the conventional theory, sugar pools peaked in the dormant season and starch pools in the growing season. Seasonal depletion of total NSCs was minimal at the whole-tree level, but substantial at the organ-level, particularly in branches. Surprisingly, roots were not the major storage organ as branches stored comparable amounts of starch throughout the year, and root reserves were not used to support springtime growth. Additionally, we examined the radial distribution of NSC concentrations in the stemwood and how it varied across the seasons. By scaling up NSC concentrations to the ecosystem-level, we found that commonly-used, process-based ecosystem and land surface models all overpredict NSC storage. Thus, our results improve our understanding of C dynamics at both the whole-tree and ecosystem levels and, importantly, resolve how the dynamics of individual organs contribute to the overall C balance.

104-6 GAGLIARDI, S F*; COMBES, S A; University of California-Davis; *gagliardi@ucdavis.edu*
Effects of Symmetric vs. Asymmetric Wing Damage on the Stability and Maneuverability of Bumblebees
Bumblebees are diligent foragers whose wings amass significant, non-repairable damage in the form of wing area loss due to frequent collisions throughout their lives. Wing damage has been directly linked to individual mortality, but the changes in flight performance that underlie this phenomenon remain unclear. Previous work has shown that experimentally inflicted wing damage reduces a bee's maximum acceleration during collision avoidance when ~20% of wing area is lost from both wings, but this effect is not significant for asymmetric damage to only one wing. The effects of asymmetric vs. symmetric wing damage on other aspects of maneuvering (such as tracking) and stability in complex aerial environments have not been tested, however. We filmed 25 *Bombus impatiens* flying in a 2.55 m/s headwind in three conditions: while tracking a flower oscillating laterally at 1.5Hz, in unsteady, vortex flow behind a vertical cylinder, and while tracking an oscillating flower in unsteady, vortex flow. Each bee was tested in all three conditions with three different wing treatments: intact wings, asymmetric wing damage (one forewing clipped ~20%), and symmetric damage (both forewings clipped ~20%), for a total of 9 flight trials per bee. We tracked three points on the thorax and used these to calculate changes in body position and orientation during flight. We found that both asymmetric and symmetric wing damage impair pitch and roll stability, and that wing damage negatively impacts maneuvering performance in the context of tracking. These results enhance our understanding of the ways in which wing damage affects insect flight performance, and highlight the importance of structural and behavioral mechanisms for mitigating damage associated with collisions.

39-3 GAJEWSKI, ZJ*; STEVENSON, LA; PIKE, D; ROZNIK , EA; JOHNSON, L; Virginia Tech, Northern Australia Quarantine Strategy, Rhodes College, Memphis Zoo; *gzach93@vt.edu*
Varying temperature effects on the growth of the amphibian chytrid fungus
Temperature is an important driver and constraint on life history traits of many organisms. Temperature can also impact disease systems, for instance by influencing traits like growth or reproductive rate of pathogens and hosts. For example, in the amphibian chytrid fungus system *Batrachochytrium dendrobatidis* , temperature is likely a key factor determining the infection rates of frogs. The role of temperature in disease systems has often been studied primarily with highly controlled experiments where the temperature is held constant. Extrapolating from the constant temperature experiments to temperature regimes more like those experienced under natural conditions is difficult and the theory relatively under-developed. One of the most common methods used to predict the effect of varying temperature on performance traits, based on constant temperature data, is rate summation. Recent work has indicated that rate summation performs poorly when tested directly in the lab. We seek to test this method in the amphibian chytrid fungus system while incorporating uncertainty in the fitting process. More specifically, we fit a Bayesian hierarchical logistic model to the optical density data that span 10 temperatures (13oC to 28oC), were the logistic growth rate is constrained by a Briere function. Posterior samples of parameters determining the shape the Briere function takes are then used to make predictions about how chytrid grows in varying temperature regimes. Data from the varying temperature experiments are then contrasted with the predictions. We find that, even including uncertainty in the parameter estimates, rate summation does a poor job of predicting growth under a time-varying temperature regime. This highlights the need for new theory to link constant and time varying temperatures.

6-3 GALASKA, M.P.*; LIU, G; BRACCO, A; QUATTRINI, A.M.; ETNOYER, P.J.; HERRERA, S; Lehigh University, Georgia Institute of Technology, Harvey Mudd College, NOAA NCCOS; *mattgalaska@gmail.com*

Comparing patterns of connectivity for mesophotic and deep-sea corals in the Gulf of Mexico.

Conservation of vulnerable marine ecosystems is imperative in the light of global ocean change and increasing anthropogenic disturbances. To help address these issues, marine protected areas (MPAs) have been established in an effort to manage and reduce the overall impact of anthropogenic activities and serve as a key strategy for restoration of benthic communities in response to catastrophes such as the Deepwater Horizon (DWH) oil spill in the Gulf of Mexico. As marine systems are often considered "open" with few barriers to gene flow, understanding what factors promote or impede genetic connectivity over depth and horizontal spatial scales of key structure forming foundation species is important for management and conservation. Species that occupy deeper depth ranges are hypothesized to have greater genetic connectivity than shallow water species, implying that management plans need to be tailored to communities of varying depths. To address these concerns, we have investigated the genetic connectivity of four different coral species occupying three putative depth ranges: mesophotic (70-150 m), upper continental slope (400-1,100 m), and lower continental slope (1,300-2,400 m). Further, we have incorporated physical oceanographic modeling approaches with our population genomic analyses. We will present comparative population genetic structure at different depths, including directionality analyses, and relative rates of genetic exchange among coral populations with integrated outcomes from predictive larval dispersal models. These results were produced in collaboration with resource managers and will be utilized in management decisions for conservation and restoration of benthic habitats in the Gulf of Mexico.

109-2 GALL, MD*; DE KONING, M; MATTHEWS, M; BEATINI, JR; PROUDFOOT, GA; Vassar College; *megall@vassar.edu*

Morphological drivers of Northern saw-whet owl directional auditory sensitivity

Many animals use cues derived from sounds arriving at two ears that are segregated in space to localize sound sources. Animals can also use monoaural cues, such as location based amplitude or spectral profiles, to localize sounds. In mammals these amplitude and frequency responses are thought to be generated by the soft tissue of the pinna, while in barn owls (Tyto alba) they are generated by soft tissue and the facial ruff. Some species, like Northern saw-whet owls (Aegolius acadicus), have not only soft tissue asymmetry, but asymmetry of ear placement in the skull itself. Previously, we used auditory evoked potentials to measure the response of each ear to sound sources placed in different locations around the head. We found that the response at each ear was influenced strongly by the location of the sound source in space. The response amplitude changed most dramatically with elevation and the latency changed most dramatically in the azimuth. Yet, we still know little about the relative contribution of the feathers, soft tissue, and bony morphology to the previously described directional sensitivity. Here we will first discuss the effect of the body, feathers, and skull morphology on the amplitude of sounds recorded with intracranial microphones placed at the tympanum. Then, we will discuss the relative contribution of body, feather and skull-driven sound amplitude differences to directional responses of the auditory nerve, as assessed by auditory evoked potentials.

S12-3 GAMBLE, t; marquette university; *anthony.gamble@marquette.edu*

Genome evolution and the origins of gecko adhesion

Keratin proteins are an important component of the tetrapod integument. Duplication and diversification of keratin genes is associated with the origin of novel integumentary structures like mammalian hair, avian feathers, and scutes covering turtle shells. Accordingly, the loss of integumentary structures can result in loss of keratin genes. For example, many of the hair keratins in dolphins and whales have become pseudogenes. The adhesive setae of geckos and Anolis are composed of both alpha- and beta-keratins and recent whole genome assemblies of a gecko and anole uncovered duplications in seta-specific beta-keratins in each of these lineages. While anoles evolved adhesive toepads just once, geckos have gained and lost adhesive toepads multiple times. The repeated evolution of gecko adhesive toepads suggests two alternative hypothesis: 1) ancient duplications of keratin genes in the most recent common ancestor to geckos that "pre-adapted" geckos to evolve adhesively-competent subdigital setae; or 2) repeated diversification of keratin genes in each lineage with an independently derived functional adhesive system. A further hypothesis asks whether secondarily padless geckos have lost functional keratin genes? I will summarize our current knowledge of keratin gene evolution in geckos and discuss how gecko genome assemblies, combined with phylogenies of keratin genes and gene duplication models, can provide rigorous tests of these hypotheses. This includes a taxon sampling strategy for sequencing and assembly of high quality genomes to investigate the origins and evolution of gecko adhesive toepads.

46-2 GAMEL , K. M.*; FLAMMANG, B. E.; New Jersey Institute of Tech, University of Akron, New Jersey Institute of Tech/ Rutgers University ; *kmg205@zips.uakron.edu*

Modeling evolutionary selection for performance, in the case of the remora adhesive disc

Fishes of the family Echeneidae, colloquially known as the Remoras, have evolved a unique and complex cranial adhesive disc from dorsal fin spines, which allows the remora to successfully adhere to different surfaces under high drag conditions. After examining the 9 known species of extant and extinct remoras in context of their phylogeny, we observed a trend in which species thought to have evolved later have more lamellae comprising their adhesive disc. We hypothesize that adhesive performance increases with number of lamellae, thus favoring selection for more lamellae over time. To investigate the effect of lamellae number on performance, we designed and fabricated a simplified remora disc model, in which we could modify the number of lamellae, and attached the disc to a variety of different roughness surfaces under varied shear conditions. We found that the number of lamellae in the disc had a nonlinear positive correlation to time to failure, suggesting that selection for adhesive performance may have contributed to variation of lamellar number among remora species.

P3-37 GANLEY, AM*; JASTREBSKY, RA; BARTOL, IK; Old Dominion University, Norfolk, VA, Holderness School, Plymouth, NH; *aganl001@odu.edu*

Maneuvering Performance of Squid: Coupling Kinematics with 3D Velocimetry

Maneuvering is an important component of routine swimming, playing important roles in predator avoidance, prey capture, and navigation. In many squid, multiple propulsive systems and control surfaces are used independently or in concert to perform impressive unsteady maneuvers, such as rapidly changing swimming direction and quickly adjusting trajectory or orientation according to predator or prey behavior. Despite its ecological significance, little is known quantitatively about turning performance in squid, especially metrics like angular velocity and turning radius and the linkage between propulsor/control surface movements and hydrodynamics. To better understand maneuvering in squid, we studied brief squid *Lolliguncula brevis* and longfin squid *Doryteuthis pealeii* as they performed turns in an observation tank using high-speed videography and volumetric (3D) velocimetry. A range of turning categories were identified, ranging from tight rotational (short turning radius) maneuvers with prominent vortex ring flows to broader translational (large turning radius) turns associated with longer, often less-defined regions of concentrated vorticity. Both the fins and pulsed jet were integral for turning, but their relative contributions to rotational torque changed with turning category. Differences in propulsor and control surface usage between the two species correlated with performance metrics, such as angular turning velocity and length-specific turning radii. Our results suggest that the fins and jet work in tandem to achieve a wide diversity of turns and interspecific differences in propulsive/stabilizing systems can affect turning performance.

P2-244 GANNON, JL*; DAVIS, JS; High Point University; *jkrisfal@highpoint.edu*

3D Geometric Morphometric Analysis of Xenarthran Masticatory Morphology

Members of the superorder Xenarthra (sloths, anteaters, and armadillos) have an evolutionary history of insectivory and an associated reduction in dentition, including decreased tooth count, simplified occlusal topography, and loss of enamel. As folivores, sloths specialize on a dietary niche not shared by their closest living relatives. Most mammalian herbivores have highly complex cheek teeth for mechanically processing plant materials, thus, the reduced dentition found among xenarthrans (sloths; Pilosa: Folivora) appears incompatible with their diet. However, in other morphological characteristics, the sloth masticatory apparatus exhibits similarities to non-xenarthran mammalian herbivores. The aim of this study is to characterize the masticatory apparatus of sloths in order to identify the morphological characteristics that correlate with and are likely to mechanically facilitate their folivorous diet. Digital scans of xenarthran skulls and jaw bones, representing 17 different species, were examined via 3D geometric mephometric analysis and the masticatory morphology of sloths was contrasted with that of their relatives.

90-6 GARCIA, MJ*; SRIRAM, A; LITTLER, A; TEETS, NM; Univ. of Kentucky; *mjga237@uky.edu*

Genetic Variance in Cold Tolerance and its Molecular Underpinnings

The ability to rapidly respond to low temperature is critical for insects and other ectotherms living in thermally variable environments. The gene *Frost* (*Fst*) and members of the *Heat Shock Protein* (*HSP*) family are rapidly upregulated following cold shock in *Drosophila* and other insects, and knockdown experiments have demonstrated these genes are essential for survival following cold stress. However, there is conflicting evidence regarding the role of *Fst* in cold tolerance, and the extent to which variation in *Fst* and *HSP* expression corresponds with genetic variation in cold tolerance is unknown. Here we tested the hypothesis that genotypic variation in cold tolerance is associated with variation in baseline expression and induction of these genes. We measured five common cold tolerance traits across 12 isogenic lines from the *Drosophila* Genetic Reference, and all of these traits showed significant genetic variation. However, while some lines performed well in all or most measures of cold tolerance, in general cold tolerance traits were not correlated across the lines, suggesting each trait may have distinct underlying mechanisms. Gene expression analyses of *Fst* and *HSPs* are underway, with initial results from a single genotype showing upregulation of both genes following cold shock. Ultimately, our results indicate the extent to which cold tolerance traits are genetically correlated and enhance our understanding of the molecular underpinnings that drive natural variation in cold tolerance.

117-5 GARCIA, PA*; DEBAN, SM; JONES, MEH; LAPPIN, AK; California State Polytechnic Univ., Pomona, Univ. South Florida, Natural History Museum, London; *pabloagarcia@cpp.edu*

Effects of Bite Out-Lever and Gape Angle on Bite-Force Performance in the Brown Anole (Anolis sagrei)

When a typical vertebrate bites, bite out-lever (i.e., distance from jaw joint to location of the bite on the tooth row) and gape angle are two variables influenced by its behavior that are expected to affect bite-force performance. As bite out-lever increases, the law of the lever indicates that bite force should decrease following a linear relationship with a predictable slope. For gape angle, existing theoretical models and empirical data from mammals generally indicate that bite force is expected to increase with decreasing gape angle. To examine the effects of bite out-lever and gape angle on bite force in lizards, we conducted *in situ* experiments in which the jaw-adductor muscles of euthanized brown anoles (*Anolis sagrei*) were stimulated directly while bite force was simultaneously measured with a double-cantilever beam force transducer. Comparing our empirical results with a model we developed, we found that bite force in the brown anole largely follows the law of the lever. With respect to gape angle, the results of a separate set of experiments show that bite force is greatest at small gape angles, though brown anoles are capable of generating relatively strong bites across a range of gape angles. The generality of these results is uncertain, given that many lizards exhibit various forms of cranial kinesis. Cranial kinesis, including streptostyly observed in anoles, may affect jaw muscle levers, lines-of-action, and length-tension properties during biting, such that basic lever mechanics are not entirely predictive of how bite force is affected by bite out-lever or gape angle.

P2-260 GARCIA RAMIREZ, J*; ROBERTSON, JC; Westminster College, PA; *robertjc@westminster.edu*

Growth and Structure of Gill Rakers in Paddlefish (Polyodon spathula)

Shortly after hatching, larval/early-juvenile stage paddlefish go through a profound series of morphological, behavioral and physiological changes - including changes in pigmentation, growth of a rostrum, and shifts in feeding. Another major transformation occurring during this dynamic period is the growth of large numbers of long, fine gill rakers; these structures are critical for the filter-feeding lifestyle of juvenile and adult paddlefish. Using histology and image analysis, this report details the development and growth of gill rakers in larval and juvenile paddlefish. Numbers of rakers, their lengths and inter-raker spacing are quantified for young fish of various sizes. Cell and tissue features associated with the growing gill rakers are also characterized. Understanding gill raker development and characteristics can lead to a more integrated understanding of the dramatic changes occurring during the critical larval-juvenile period in this species. For example, the ram ventilation filter-feeding of larger paddlefish requires anatomical accommodation (optimized gill rakers) as well as behavioral correlates. We also report comparative results of gill raker analysis for related Acipenseriformes - Atlantic sturgeon (*Acipenser oxyrinchus*) and lake sturgeon (*Acipenser fulvescens*). Comparison of these species allows consideration of the relationships between gill raker structure and diet and feeding behavior in this order of basal ray-finned fishes. Greater understanding of feeding mechanisms and behaviors throughout development in paddlefish may have application in conservation efforts.

133-4 GARDNER, S*; ASSIS, VR; APPEL, A; MENDONÇA, MT; Auburn University, University of Sao Paulo; *stg0015@tigermail.auburn.edu*

Immunity vs dispersal of Florida cane toads: physiological responses to LPS

Invasive species are predicted to have decreased immunity compared with conspecifics from more established ranges, specifically inflammatory responses that may be energetically costly and decrease dispersal. Populations of the invasive cane toad, introduced into Florida in the early 1930's, have recently spread northward through the state. To determine if toads near the invasion front in Florida have predicted differing immune responses, toads were collected from a southern core (Miami-MIA) and northern invasion front population (New Port Richey-NPR), and given an immune challenge with lipopolysaccharide (LPS). Toads were injected with either saline (n = 5 and 6, MIA and NPR, respectively) or 20 µg/gram of body mass with LPS (n = 11, 9 (MIA, NPR respectively)), and metabolic rates were measured for 20 hr. Toads were bled at 20 hr, and we measured plasma corticosterone (CORT) levels and bacteria killing ability (BKA). Toads injected with LPS had significantly higher metabolic rates during the 20 hr following injection compared with saline-injected toads ($p = 0.018$), although metabolic rates of LPS-injected toads did not differ between the populations ($p = 0.27$). CORT levels of toads injected with LPS at 20 hr were not different than saline-injected toads for either population at 20 hr ($p = 0.24$), although, regardless of treatment, toads from NPR had significantly higher CORT levels than MIA toads ($p = 0.025$). At 20 hr, BKA of LPS-injected toads was significantly higher than saline-injected toads ($p = 0.0008$), with Miami toads having significantly higher BKA than NPR ($p = 0.009$). Although further studies are needed, CORT differences between the populations, and BKA differences between the populations responding to LPS, could provide support to predictions by the EICA hypothesis.

P2-236 GARDNER, S*; ASSIS, VR; HORNE, M; MENDONÇA, MT; Auburn University, University of Sao Paulo; *stg0015@tigermail.auburn.edu*

Evaluating toxicity of Florida cane toads: gland sizes and poison secretion

Invasive species can harm native fauna through competition and predation, and toxic invaders can poison native predators. Cane toads, introduced to several locations around the world, have been reported with larger parotoid (poison) glands near the invading front in Australia, indicating higher risk to naïve predators. To assess relative toxicity of Florida cane toads in terms of gland sizes and likelihood of secreting poison, approximately 20 toads per population were captured and placed into plastic bags from 9 Florida populations. Following one hour of capture, toads were removed from the bags and mass, sex, and snout-vent-length (SVL) were recorded. Toads were placed next to a ruler and images were obtained to measure gland sizes, with images also showing if a toad was secreting poison following this handling period. Measurements of total length, width, and area of glands were performed using Image J software. An ANCOVA using the first component of a principal component analysis ("small gland size") of Log-transformed gland length, width, and area, was used to explain morphological differences among Florida toads. Gland sizes increased with increasing body mass ($p = 0.019$), although they were not significantly affected by latitude. Using a generalized linear model to assess likelihood of poison secretion, toads were twice as likely to secrete following capture and handling with every degree of increasing latitude ($p = 0.038$). Although gland sizes of Florida toads didn't significantly change with latitude, the likelihood of toads secreting poison as distance from the introduction point increases in Florida is similar to Australian cane toads, and may indicate relative toxicity increases with increased dispersal.

P3-9 GARNER, AM; PAMFILIE, AM*; DHINOJWALA, A; NIEWIAROWSKI, PH; The University of Akron; *amp183@zips.uakron.edu*

Relationships between Adhesive Performance and Substrate Preference Behavior in Tokay Geckos (Gekko gecko)

The past several decades of research into gecko adhesive system performance, morphology, and ecology have uncovered a stunning array of results. The gecko adhesive system is apparently able to adhere to a wide variety of surfaces, including those that are rough. However, some recent work suggests that the contact setae are capable of generating may be greatly diminished on rough surfaces. A handful of laboratory studies have investigated gecko adhesive performance on rough surfaces, but it is still unclear how surface roughness at a variety of length scales impacts gecko adhesion. Here, we attempt to determine if gecko adhesive capacity is reduced on a rough surface of interest and whether geckos, if, when given a choice, will avoid using this surface.The results of this study will provide additional data detailing how surface roughness impacts gecko adhesion, and also give a starting place for future studies investigating how adhesive performance may be related to substrate preference and habitat use in free-ranging geckos.

31-7 GARNER, AM*; KLITTICH, MR; MAKSUTA, D; NIEWIAROWSKI, PH; DHINOJWALA, A; University of Akron; *amg149@zips.uakron.edu*

The Role of Surface Lipids in the Self-Cleaning Ability of Gecko Subdigital Adhesive Pads

Recently, phospholipids have been discovered on the setal surfaces of the gecko adhesive system. These surface lipids have been hypothesized to affect a number of properties of gecko adhesive setae, including underwater adhesion/superhydrophobicity, ease of release, wear prevention, fibril condensation, and self-cleaning. Presently, surface lipids do not affect the adhesion of gecko toe pads underwater or their anti-wetting properties. Interestingly, however, removal of surface lipids directly results in increased adhesion on dry, hydrophilic surfaces, suggesting that removal of surface lipids corresponds to subsequent increases in setal surface energy. A potential increase in setal surface energy could have detrimental effects on many of the above-mentioned properties. Indeed, the surface energy of setae is critical in the self-cleaning property of gecko toe pads, as the adhesion energy between setae and dirt particles is generally lower than the adhesion energy between dirt particles and the substrate. Here we present data demonstrating the effect of surface lipids in the self-cleaning ability of gecko subdigital adhesive pads. We chemically removed surface lipids and measured resultant changes in the efficacy of gecko self-cleaning. The results of this study highlight the multifunctional capacities of the gecko adhesive system, which are not only important ecologically, but also important to the design and fabrication of multifunctional gecko-inspired synthetic adhesives.

P3-10 GARNER, AM*; WILSON, MC; RUSSELL, AP; NIEWIAROWSKI, PH; DHINOJWALA, A; University of Akron, University of Calgary; *amg149@zips.uakron.edu*

Morphometrics and Patterning of the Adhesive Setal Fields of an Anolis Lizard in Comparison to those of its Gekkotan Counterparts

The remarkable ability of geckos to adhere to surfaces has served as inspiration for hundreds of studies spanning the disciplines of biomechanics, chemistry, ecology, evolution, functional morphology, material science, and physics. Fibrillar adhesive systems have independently evolved in two other lineages of lizards (anoles and skinks), but comparatively little is known about the fibrillar characteristics of these convergent adhesive arrays. This is particularly surprising for *Anolis* lizards, because anoles have been the subject of intensive ecological and evolutionary study for several decades. The morphology and patterning of the adhesive setae of several species of geckos has been comprehensively examined, with patterns of variation in setal length, diameter, density, and other morphological characters being revealed along the proximodistal axis of the subdigital adhesive pads. In contrast, such potential variation in the configuration of setal fields in *Anolis* lizards remains largely unexplored. Indeed, the only data that are currently available relate to single gross setal dimensions of a few species. Here we describe preliminary setal morphometrics and patterning data for an *Anolis* lizard and compare this to the patterns reported for gekkotan setae. Our results not only add to the diversity of existing morphometric data for lizard fibrillar adhesive systems, but also stand to serve as additional sources of inspiration for biomimetic fibrillar synthetic adhesives.

1-6 GARROD , H.M*; CURRY , R.L.; Villanova University ; *hmg20@humboldt.edu*

A tale of two todies: how vocal behavior influences mate choice in two tody species

Cases of sympatry, where closely related species inhabit the same region, offer unique insight into the mechanisms responsible for reproductive isolation and speciation. Birds are a taxon where sympatric species frequently hybridize (9% of species) and behaviors such as song often influence mate choice. While songbirds learn both their song and preference, many other birds, including the Todidae family, have innate vocalizations that still play a role in mate choice. Todidae is endemic to the Caribbean and includes five species spread across four islands, with Hispaniola the only island to have two species occurring sympatrically. For this study, I aimed to use behavioral analyses to assess if hybridization could occur between the Broad-billed and Narrow-billed todies. I conducted paired-speaker playback experiments in three sympatric and three allopatric sites for each species to compare how both Todus spp. respond to conspecific and heterospecific vocalizations. Preliminary analyses suggest no responses to heterospecifics in either species in allopatric zones, but stronger response to heterospecifics at sympatric sites. Further elucidating these responses will help determine if hybridization could occur, or if vocal responses aid in preventing it. Understanding how these birds behave with heterospecifics could have implications for understanding species barriers in other sympatric sites.

P1-55 GARROTT, M.*; LAUN, A.; United States Naval Academy; *m191986@usna.edu*

Biomimetic Caudal Fin for an Unmanned Underwater Vehicle (UUV)

A typical propulsion system for an unmanned underwater vehicle (UUV) features a rotating shaft and a propeller to forcefully push the hull through the water. While efficient, such a vehicle design can result in reduced maneuverability and agility. The caudal fins of many fish suggest potential designs that could provide reasonable efficiency, as well as improved maneuverability. For example, the heterocercal caudal fins of many sharks, such as *Triakis semifasciata*, *Galeocerdo cuvier*, and *Isurus oxyrinchus* appear to be effective shapes that balance propulsive efficiency and maneuverability. Key aspects of such fins are their shape, flexibility, and the tail-angle between the fin's lobes and the fish's body. This presentation discusses efforts to design and optimize an undulating, neutrally-buoyant caudal fin attachment for a common UUV hull-form. Specifically, optimizing the geometric shape and tail-angle for improved flow behavior and maneuverability results in a design similar to actual sharks, such as *Triakis semifasciata*, *Galeocerdo cuvier*, and *Isurus oxyrinchus*. Integration of the biomimetic caudal fin into an existing UUV propulsion system is anticipated to provide superior hydrodynamic performance, efficiency, and maneuverability.

41-4 GART, SW; FU, Q; MITCHEL, TW; LI, C*; Johns Hopkins University; *chen.li@jhu.edu*
Snakes partition their body to traverse large steps and inspire a snake robot
Many snakes traverse complex 3-D terrain such as mountains and forests with obstacles comparable to their body size. Similarly, snake robots have the potential to traverse terrain with large obstacles like earthquake rubble and construction sites for search and rescue and structural examination. However, with the exception of branch climbing, burrowing, and gliding, laboratory studies of snake locomotion focused on that on simple flat surfaces. Here, to understand snake locomotion in complex 3-D terrain and provide inspiration for snake robots, we study how the generalist variable kingsnake traversed a large step as high as 40% body length. The snake partitioned its body into three sections that deformed in separate planes with distinct functions. The body sections below and above the step oscillated laterally on the horizontal surface to stabilize and propel the animal forward. The body section in between straightened and cantilevered in a vertical plane to bridge the large height increase. All three sections travelled down the body fluidly as the animal progressed, allowing the snake to always conform to the terrain. In addition, despite changes in step height and surface friction, this movement pattern persisted. To test this gait as a control template for robots, we developed a snake robot capable of horizontal and vertical body deformation with anisotropic friction as found in snakes. Using a partitioned gait, the robot traversed a step as high as 30% body length with 100% probability and at speeds surpassing previous snake robots that used artificial, follow-the-leader gaits. However, as step height further increased to 40% body length, the robot failed more often due to diminishing stability and traction from poorer body-terrain contact (another talk by Fu Q et al. discusses how body compliance helps alleviate this problem).

P1-235 GASS, J.T.*; NISHIGUCHI, M.K.; New Mexico State University; *jtgass@nmsu.edu*
Zombie bacteria: using natural transformation to study bioluminescence in the Vibrio fischeri-Euprymna scolopes symbiosis
The beneficial bioluminescent marine bacterium *Vibrio fischeri* has been used to study mechanisms of symbiont specificity, host recognition, and evolutionarily driven trade-offs in environmentally transmitted associations with animal hosts (Cephalopoda: Sepiolidae). *V. fischeri* bacteria colonize the squid light organ where bacterial bioluminescence is produced in order to provide the squid with the ability to counterilluminate. Given that many of the regulatory elements in *V. fischeri* are controlled by the host environment, understanding how such cross talk occurs *in vivo* will shed light on bacterial-host interactions. Therefore, we investigated the feasibility of using chitin induced natural transformation in *V. fischeri* to introduce linear ds DNA expression cassettes, which are designed to integrate at targeted sequences within the *V. fischeri* genome via homologous recombination. This technique is ideally suited to determining host specificity and other aspects of symbiosis. We initially targeted the *luxA* gene within the *lux* operon, which is responsible for generating the luciferase-based bioluminescence produced by *V. fischeri*. Using a targeted insertional knock-out of the *luxA* gene along with an insertional complement of *luxA*, we can study the regulation and modulation of bioluminescence production in the dialog between host and symbiont, which allows for a stable, beneficial association. The on-going development of efficient genetic modification techniques are a vital link in understanding the interdependent connections between host species and their symbionts.

P3-56 GASSLER, TR*; FLAMMANG, BE; New Jersey Institute of Technology; *trg22@njit.edu*
3-D MODELING OF WALKING AND PUNTING IN THE LITTLE SKATE, Leucoraja erinacea
Skates are known to locomote using the anterior lobe, or crura, of their pelvic fins to push off the substrate. Skates have two non-swimming locomotor modes: "walking" via alternating pelvic fins, and "punting", which uses simultaneous bilateral movements of their pelvic fins. It has recently been shown that the Hox genes responsible for limb development in the little skate, *Leucoraja erinacea*, are the same as those found in terrestrial vertebrates (i.e. mice). Previous studies showed the morphology of the pelvic girdle and the kinematics of walking resemble that of a sprawled-gait terrestrial tetrapod (i.e. salamanders). The next step to understanding the locomotion employed by skates is to investigate neuromotor control of the muscles. The pelvic area of *L. erinacea* (puboischiadic bar, fins, and spinal column) was µCT scanned to observe the skeletal elements. The area was then stained with phosphotungstic acid (PTA) and rescanned to visualize the musculature. These scans were reconstructed with Mimics software and used to create and animate a morphologically-based 3-D digital model in the program Maya. The physiological cross-sectional area (PCSA) of the muscles was calculated and the maximum force generation of each muscle involved in locomotion was estimated to use as parameters in the model. This model allowed us to simulate different aspects of muscle stimulation/timing and to investigate the kinematics, biomechanics, and motor modulation of both walking and punting. These data will be used in future projects to compare the model to electromyography (EMG) of *in vivo* little skate muscles.

104-8 GAU, JF*; GRAVISH, N; SPONBERG, S; Georgia Institute of Technology, Univ. of California, San Diego; *jeff.gau@gatech.edu*
Effects of Shape, Material, and Musculature on Energy Exchange Capacity in the Hawkmoth Thorax
Elastic energy exchange is thought to offset the high power requirements of insect flight. For significant elastic return, a structure must be stiff to store energy and resilient (energy return/energy in) to minimize dissipation. Structures that may serve this role are the viscoelastic musculature and thoracic exoskeleton, which contains highly resilient proteins. We have shown that the exoskeleton of the hawkmoth *Manduca sexta* can return up to 20% of inertial power requirements with a 75% resilience over a wide frequency range. However, thoracic material properties, shape, and musculature may all contribute to this storage and return. Using a custom material testing device, we measured the force required to drive sinusoidal displacements of the thorax in four experimental conditions: 1) longitudinal cuts disrupting the transverse arch, 2) cuts through the wing joints to isolate the curved scutum, 3) isolated wing joints with scutum removed, and 4) intact thorax with passive muscles. We examined a frequency range from 0.1 to 90 Hz to span the hawkmoth's wingbeat frequency of 25 Hz. Each of the three cut conditions led to decreased stiffness (27 ± 7%, 49 ± 12%, 67 ± 21%). While resilience also decreased (9 ± 0.4%, 18 ± 1%, 20 ± 3%), the response was not proportional to the stiffness change, indicating an increased structural damping coefficient (37 ± 4%, 77 ± 8%, 66 ± 24%). The presence of muscle had no significant effects. Videos of thorax deformation show non-uniform strain, indicating that shape alters localized strain. Changes in local strain coupled with material heterogeneities may affect macroscopic behavior. Overall, material alone cannot predict mechanical properties. Shape matters for thoracic energy exchange.

3-5 GEHMAN, A-L. M*; SCHAEFFER, O.; HARLEY, C.D.G.; University of British Columbia, Hakai Institute, University of British Columbia; *alyssamina@gmail.com*

Environmental drivers of host defense and the cost of parasitism

Parasites can exacerbate or buffer host response to environmental conditions, and thus hosting a parasite can affect host performance. Likewise, environmental context can alter parasite performance directly, creating a range of host-parasite interactions across environmental gradients. Extant variation in species interactions across environmental gradients could give us insight into how species will respond to climate change. Using field outplants, we examine growth of a shell-boring endolithic cyanobacteria and its mussel host, "*"Mytilus californianus"*" across an intertidal gradient. To isolate erosion rate from mussel growth rates, we paired dead shells with living mussels across the intertidal. To evaluate mussel defense we sequenced the microbial communities associated with the mussel shells. The proportion of mussels that are eroded by endolithic cyanobacteria varies across the intertidal, with high levels of erosion in the upper intertidal and low levels in the lower intertidal. We found that mussel growth rates were highest in the lower intertidal, and that erosion rates were highest in the upper intertidal. Live mussels had lower erosion rates then dead mussels, but only in the lower intertidal. Microbial communities varied across the intertidal and between live and dead mussel shells, suggesting that shell microbial communities could be related to mussel defense against biotic erosion.

P1-45 GELLMAN, ED*; TANDLER, T; DE LA CRUZ, DB; ELLERBY, DJ; Wellesley College; *dellerby@wellesley.edu*

Drag Coefficient Estimates from Coasting Bluegill Sunfish (Lepomis macrochirus)

Bluegill sunfish (*Lepomis macrochirus*) coast frequently during volitional swimming powered by body and caudal fin undulations, and maintain a straight body-axis during labriform propulsion with the pectoral fins. Inertial drag is therefore functionally important for this species. The drag coefficient estimated from coasting deceleration was 0.015 ± 0.007 at a Reynolds number of 41000 ± 14000 ($\pm$ 1sd). This was within the coasting range in other species, and lower than values obtained from ‘dead drag' measurements in this species and others. Low momentum losses during coasting may allow its use during intermittent propulsion to modulate power output or maximize energy economy.

127-6 GEMMELL, B. J. *; COLIN, S. P.; COSTELLO, J. H. ; SUTHERLAND, K. R. ; University of South Florida, Roger Williams University , Providence College , University of Oregon , University of South Florida Tampa; *bgemmell@usf.edu*

Bouncing off the (non-existent) walls: Using the vortex rebound phenomenon to outswim your peers

Body-vortex interactions are widely recognized as an important component in the effective locomotion of swimming and flying animals. It is less clear how vortex-vortex interactions contribute to animal movement in a fluid. Gelatinous zooplankton are a diverse group that exhibit a wide range of propulsive swimming modes. One of the most energetically efficient modes is a type of pulsation behavior, known as rowing, which is used by many species of jellyfish. Another type of gelatinous swimmer is the ctenophore, or comb jelly. These animals typically use a slow, cilia-based mode of propulsion. However species within the genus *Ocyropsis* have developed an additional propulsive strategy of rowing the lobes, which are normally used for feeding, in order to rapidly escape from predators. In this study, we used high speed digital particle image velocimetry (DPIV) to examine the kinematics and fluid dynamics of this rarely studied propulsive mechanism. This mechanism allows *Ocyropsis* to achieve size-adjusted speeds that are nearly double those of other large gelatinous swimmers. Investigation of the fluid dynamic basis of this escape mode reveals novel vortex interactions that have not previously been described for other biological propulsion systems. The arrangement of vortices during escape swimming produces a vortex configuration that behaves in the same manner as the well-studied ‘vortex rebound' phenomenon, which occurs when a vortex ring approaches a solid wall. We discuss how this vortex arrangement can allow for a greater reaction force and overall thrust. These results extend our understanding of how animals utilize vortex-vortex interactions and provide important insights that can inform the bio-inspired engineering of propulsion systems.

85-4 GEORGE, EM*; BENTZ, AB; WOLF, SE; ROSVALL, KA; Indiana University Bloomington; *georgee@indiana.edu*

Testing hormonal responses to real and simulated social challenges in a competitive female bird

In many vertebrate species, males respond to competitive interactions by rapidly elevating testosterone (T) levels in circulation. Though there is growing evidence that aggression can also be adaptive for females, and that females can synthesize and respond to T, we still lack a full understanding of how females hormonally respond to social challenges. Tree swallows (*Tachycineta bicolor*) are an ideal system in which to explore this issue because females compete for limited nesting cavities, and their aggression is at least partly mediated by T. Here, we measured circulating T levels in pre-laying females that were exposed to 30 min simulated territorial intrusions, compared to stage-matched controls. In a separate experiment conducted after initial territory establishment, we experimentally reduced the availability of nesting cavities, allowing us to compare T levels in females experiencing real social instability to those of controls. Results suggest that female tree swallows do not elevate T levels in circulation after behaving aggressively toward real or simulated competitors. This apparent lack of T elevation stands in sharp contrast to prior work showing that females are physiologically capable of elevating T (i.e. to GnRH) during this same breeding stage. Collectively, these results provide new insight into how females do (or do not) respond to social competition, raising new questions as to whether females socially modulate other hormones as an adaptive response to social challenges.

91-4 GEORGE, AB*; OLSEN, AM; WESTNEAT, MW; University of Chicago, Brown University; *abgeorge@uchicago.edu*

Swimming Kinematics Reveal Multiple Gait Transition Strategies Within Balistoid Fishes

Triggerfishes and filefishes in the superfamily Balistoidea power slow steady swimming using oscillations or undulations of their median dorsal and anal fins in a gait termed balistiform locomotion. Most balistoid fishes undergo a gait transition with increasing speed from balistiform locomotion to a gait dominated by body and caudal fin (BCF) contribution. The goal of this study was to examine trends between balistoid morphology, swimming performance and kinematics across this gait transition. In order to explore these patterns, we analyzed endurance swimming performance and gait transition speeds of 13 balistoid species. This study revealed that the initiation of the gait transition from balistiform to BCF locomotion ranged from 44% to 94% of the maximum achieved swimming speed. We then conducted geometric morphometric analyses of the fins and bodies of the 13 balistoid species and found that species with large median fins and wide caudal peduncles tend to use the balistiform gait for a larger percentage of their maximum swimming speed. Finally, we performed 3D kinematics experiments on 4 balistoid species spanning the range of observed gait transition speeds. These fishes were filmed with 3 high-speed cameras while swimming at multiple speeds in order to quantify diversity in dorsal, anal and caudal fin kinematics across the gait transition using a recently described method in which propulsive contribution of each fin is calculated as a function of its frequency and amplitude at each swimming speed. We found multiple distinct gait transition patterns and differences in fin kinematics and coordination between species, indicating that balistoid fishes adopt several gait transition strategies to achieve efficient, high-speed locomotion. NSF GRFP and NSF 1541547.

113-5 GERMAN, DP*; HERRERA, MJ; HERAS, J; Univ. of California, Irvine; *dgerman@uci.edu*

The meat sweats: the effects of increasing dietary protein content on enteric microbial diversity and digestive and metabolic outcomes in a marine herbivorous fish

The marine herbivorous fish *Cebidichthys violaceus* is considered an obligate herbivore in nature. *C. violaceus* has an expandable distal intestine in which microbial fermentation occurs and where there are microbially-derived digestive enzyme activities. We observed that as *C. violaceus* consumed more protein and less fiber, they ate less, and their distal intestine was smaller, yet the fish grew well and showed no mortality across an 8-month feeding trial on omnivorous and carnivorous diets in the laboratory. We hypothesized that the *C. violaceus* distal intestine microbial community changed in composition in response to increasing protein and decreasing fiber in its diet. Thus, we analyzed microbial diversity using 16s rRNA sequences, microbial fermentation via concentrations of short chain fatty acids (SCFA), and gut and metabolic function via transcriptomic profiles of distal intestine and liver tissue, respectively. The microbiome of distal intestine gut tissues in wild individuals and those fed an herbivorous diet were dominated by Actinobacteria and Proteobacteria, whereas digesta contents of this gut region were dominated by Bacteroidetes and Firmicutes (with B:F ratios of 5:1; more detailed analyses underway). These general phylum-level patterns varied little on an omnivorous diet, but the carnivorous diet caused a complete shift of the microbial community towards unknown bacterial taxa, and Spirochaetes. The SCFA (via gas chromatography) and transcriptomic (featuring greater than 15 million reads per sample) analyses are in progress. Overall, this study will answer whether an herbivorous fish can deal with a carnivorous diet (from digestive and metabolic standpoints) and what this means in terms of dietary specialization.

P2-231 GIAMMONA, FF*; MINICOZZI, MR; GIBB, AC; ASHLEY-ROSS, MA; Wake Forest University , Northern Arizona University , Northern Arizona University, Wake Forest University; *giamff17@wfu.edu*

Plastic changes in mass distributions in Kryptolebias marmoratus with air acclimation lead to increased performance in a terrestrial environment

Emersion from an aquatic to a terrestrial environment is a tactic used by many fish species for a variety of reasons. With *Kryptolebias marmoratus*, emersion occurs due to stranding, to escape predators, and to capture prey. Once on land, *K. marmoratus* can employ a tail-flip behavior in order to move across the substrate. The performance of this tail-flip behavior can depend on a variety of factors such as age, size, and time spent acclimating to air. In this experiment, forty *K. marmoratus* individuals were exposed to one of four different fasted acclimation treatments: 28 days in water, 14 days in air followed by 14 days in water, 14 days in air, and 14 days in water. Fish were then put on moist paper and prompted to jump. Number of jumps and distance moved during jumps were analyzed. Preliminary results show that the individuals who acclimated in air only jumped more frequently and moved further with each jump, indicating that plastic changes may occur during air acclimation that improve locomotor performance on land. To test if one of these plastic changes could be a change in mass distribution from the anterior to the posterior, where most of the force needed to jump is generated, lateral and dorsal photos were taken of fish before and after treatment. These photos were then analyzed to track changes in mass along the body. Preliminary results indicate that while most individuals lost weight, mass distribution of individuals in the 14 days in air treatment shifted towards the posterior, while mass distribution did not appear to change appreciably in the other treatment groups. Plastic shifts in mass may thus be the mechanism that allows *K. marmoratus* to perform better when jumping in a terrestrial environment after air exposure.

8-1 GIBB, AC*; MINICOZZI, MR; Northern Arizona University; *alice.gibb@nau.edu*

Changes in body size affect the biomechanics and behavior of teleost fishes

Thousands of studies have examined how the biomechanical and physiological underpinnings of movement are influenced by body size in tetrapods, particularly in terrestrial mammals. Yet, very few studies have considered how changes in body proportions (length vs. area vs. volume) and established allometric parameters for muscle kinetics dictate what behaviors can be employed and how habitats can be used by teleost fishes, the most numerous vertebrates on the planet. We note that several hallmark teleost behaviors may only be possible for individuals of certain sizes. For example, a very rapid change in buccal volume is required to produce effective suction feeding, but the muscular forces required to produce this behavior may not keep pace with increased buccal volume in large fishes. Similarly, the time to complete the "preparatory" stage of a fast-start (or C-bend) will become greater as fish grow larger, with the result that a large fish will remain in a vulnerable position for an extended period of time. In addition, because fishes live in a microgravity environment, inertial effects of increased body mass are often completely ignored. However, simple predictions based on fundamental scaling parameters yield size-based expectations for key teleost behaviors: either large fishes cannot perform these key behaviors and have eliminated them from their behavioral repertoires, or they have developed physiological or morphological "workarounds" to circumvent the problems inherent to changes in body size. Thus, best practices for fish ecologists, biomechanists, behaviorists, and physiologists are studies that incorporate predictions based on established scaling relationships for morphological/physiological parameters and test the assumptions of geometric similarity (isometric scaling) in teleost fishes.

42-3 GIBSON, J. C.*; SUAREZ, A. V.; University of Illinois at Urbana-Champaign; *jcgibso2@illinois.edu*

Deadly Jaws: Functional Morphology and Strike Kinematics of Acanthognathus Trap-Jaw Ants

High speed power-amplification mechanisms have evolved independently in many groups of organisms across the tree of life, including multiple times in ants (Hymenoptera: Formicidae). "Trap-jaw" ants possess spring loaded mandibles that allow them to swiftly incapacitate or kill elusive prey. Trap-jaw ants have the potential to serve as model organisms for studies on the relationship between morphological and functional diversity and the evolution of power-amplification mechanisms, but to date the feasibility of these studies is limited by a lack of performance data for many groups of trap-jaw ants. Here we use high speed videography and micro-CT to describe the strike kinematics and functional morphology of *Acanthognathus brevicornis*, a trap-jaw ant from the neotropics that possesses a morphologically distinct trap-jaw mechanism. *Acanthognathus brevicornis* workers have enlarged basal processes on their highly elongated mandibles that interlock when the mandibles are opened, allowing elastic energy to be stored within the head capsule as the mandible closer muscles contract. A modified section of closer muscle rotates the mandible dorsally, disengaging the basal processes and releasing the mandibles. High speed videography revealed that *A. brevicornis* mandibles close in less than 0.08 ms, reaching an average maximum velocity of 30 m/s and an average maximum acceleration of $1.2e^6$ m/s^2 over the course of a strike. Comparisons to other trap-jaw ant species revealed that *A. brevicornis* strikes conform to scaling relationships seen across trap-jaw ant groups. This study is the first to quantify the strike performance of *Acanthognathus* and is part of a larger project examining the biomechanics and evolution of power-amplified mandibles ants.

11-4 GIDMARK, NJ*; BERGER, G; RAHMAN, N; ROSENBLOOM, J; Knox College; *gidmark@knox.edu*

Evolution of body shape, jaw anatomy, and muscle physiology in Centrarchid fishes

Prey capture is a functionally integrated endeavor: the body moves to the food, the capturing tools (e.g. teeth, jaws, and appendages) interact with the food, and the muscular system is moves the body and jaws. Centrarchid fishes (37 species) are a fantastic model system for studying the integrated evolution of these systems, because they show variation in body shape and mouth shape, and because jaw-closing mechanics are governed largely by a single adductor muscle complex. We examined anatomy in this group in terms of three attributes: body shape, jaw musculoskeletal structure, and jaw-closing (adductor) muscle physiology. We used CT scans, digital photography, physical dissection, and *in situ* muscle preparations in our exploration. Our results show that diversity in this group is rich in each of those three attributes. For example, the body shape of green sunfish and largemouth bass is torpedo-like, whereas bluegull sunfish, crappie, and redear sunfish show plate-like body shapes. Interestingly, variation in body shape is not correlated directly with variation in jaw shape; crappie and largemouth bass share similar jaw shapes, despite widely different body forms. Physiological *in situ* muscle preparations (force-velocity and force-length) show high diversity in muscle performance, even with skeletal (jaw) anatomy taken into account. Preliminary analyses indicate a tighter correlation of jaw muscle physiology with jaw shape than with body form. Continuing work aims to increase the species-level sample size for muscle preparations (currently N = 4 individuals each for 5 species for force-length and N = 4 individuals each for 5 species for force-velocity experiments) to better match that of our CT scan dataset (N = 1 individual each of 37 species) and to rigorously test phylogenetic integration of these traits.

P1-151 GIGLIO, EM*; PHELPS, SM; GIGLIO, Erin; University of Texas at Austin; *eringiglio@gmail.com*

Context in courtship: the role of leptin in social investment decisions in singing mice

The ability of animals to adapt to context is one of the most important challenges facing any individual. This is particularly important when it comes to sexual signalling and courtship, when the choice to signal or not signal may determine whether or not a given animal gets to live--or whether it gets to reproduce. Signals often impose costs on individuals, including energetic, predatory, and social costs, and individuals must integrate the cost/benefit analysis of signaling before making the decision to signal or remain hidden. Leptin is an exciting potential overall signal for male animals to self-monitor because it responds to many contexual cues about body state, including energetics, immune challenge, and sleep. Here we explore the effect of leptin manipulations on investment in male advertisement song on neotropical singing mice. We administered intraperitoneal injections of mouse leptin (Mus) to male singing mice immediately before a playback protocol designed to evoke song, a social advertisement behavior. Mice injected with leptin sing back more frequently than mice injected with saline, and they have a shorter average latency to respond to playback than saline-injected mice. Interestingly, we find that these results appear regardless of fasting state prior to testing: all animals in this experiment were fed ad libitum, suggesting that variations in endogenous leptin are monitored by individuals even when leptin levels are too high to significantly alter feeding behavior.

45-7 GIGNAC, PM*; KLEY, NJ; Oklahoma State University CHS, Stony Brook University; *paul.gignac@okstate.edu*

780-sample Repeated-measures Study to Improve Visualization of Vertebrate Soft-tissue Anatomy Using DiceCT Imaging

Diffusible iodine-based contrast-enhanced computed tomography (diceCT) permits the visualization of soft-tissue anatomy at high three-dimensional spatial scales relatively rapidly and at minimal expense. However, its implementation can meet with widely varying levels of success owing to the bewilderingly complex array of variables related to specimen fixation, storage, staining, size, and µCT scanning. These can conspire to make consistent and favorable results somewhat elusive. To address this issue, we designed a 780-sample repeated-measures analysis, using pairwise grayscale differentials to systematically document and analyze the effects of these variables. We used thick (~1 cm) sections from the bodies of adult python specimens (*Liasis*, *Antaresia*) to represent standard samples of vertebrate tissues (e.g., cortical bone, spinal gray and white matter, skeletal muscle). Four size classes based on section diameter were prepared in triplicate as: (1) freshly fixed in neutral buffered formalin, (2) frozen followed by formalin fixation, or (3) freshly fixed followed by storage in ethanol, each to mimic common specimen preparations. Triplicates were stained with various exposures to iodine potassium-iodide (I_2KI) and µCT scanned to determine how size-to-iodine relationships alter tissue contrasts. Next, the best contrasted exemplars were µCT scanned under various beam settings to determine the iodine-to-power relationships that maximize these contrasts. Our results indicate that: (1) long staining durations at low concentrations of I_2KI are optimal; (2) µCT scanner settings should minimize voltage, maximize current, and enable multi-frame averaging; and (3) freshly fixed tissues are best-suited for diceCT imaging, followed by ethanol preservation and freezing.

96-1 GILBERT, RG*; PAUL, AM; BHATTACHARYA, S; NASA Ames Research Center; *rachelrgilbert11@gmail.com*

Effects of Spaceflight and Simulated Microgravity on a Host-Pathogen System

While it has been shown that decades of astronauts and cosmonauts suffer from immune disorders both during and after spaceflight, the underlying causes are still poorly understood, due in part to the fact that there are so many variables to consider when investigating the human immune system in a complex environment. Invertebrates have become popular models for studying human disease because they are cheap, highly amenable to experimental manipulation, and have innate immune systems with a high genetic similarity to humans. Fruit flies (*Drosophila melanogaster*) have been shown to experience a dramatic shift in immune gene expression following spaceflight, but are still able to fight off infections when exposed to bacteria. Furthermore, a recent study showed that flies are more susceptible to infection following spaceflight, and that the common bacterial pathogen *Serratia marcescens* is also more lethal to fruit flies after being cultured in space, suggesting that not only do we need to consider host changes in susceptibility, but also changes in the pathogen itself after spaceflight conditions. In this study, I use both spaceflight and ground-based (simulated microgravity) environments to examine the genetic changes associated with increased *S. marcescens* virulence in order to understand how microgravity is affecting this pathogen, as well as to evaluate how these genetic changes influence and interact with the host immune system. This study will provide us with more directed approaches to studying the effects of spaceflight on human beings, with the ultimate goal of being able to ameliorate human immune dysfunction in future space exploration.

P2-170 GILBERT, MC*; AKAMA, A; COX FERNANDES, C; ALBERTSON, RC; Univ. Massachusetts, Amherst , Museu Paraense Emílio Goeldi, Belém, PA, Brazil, Instituto Nacional de Pesquisas da Amazônia, Manaus, AM, Brazil; Univ. Massachusetts, Amherst ; *chaise.gilbert@live.com*

Rapid Morphological Shifts in Native New World Cichlids in Response to an Anthropogenic Alteration to a Major Clearwater River in the Amazon River System

The Tocantins River serves as the major drainage for the Tocantins and Araguaia watershed and was once a large (2,450km), contiguous system. The construction, and subsequent closure, of the Tucuruí Hydroelectric Dam (the major dam in the system) in 1984 established a large (~2,850km2) ‘permanent' reservoir, eliminating the once historic streams, floodplains, and rapids that once occupied this length of the Tocantins river. Such dramatic anthropogenic change can either lead to the extirpation of local flora and fauna, or species may be able to adapt to local environmental changes. To explore the latter possibility, we used geometric morphometrics to evaluate changes in native cichlids, incorporating both museum specimens collected prior to the closure of the hydroelectric dam (≤ 1984) and specimens collected during 2017-18. A total of six species, distributed over four genera, were included, representing distinct ecomorphs, varying from large piscivorous fishes to relatively small opportunistic omnivores. While some lineages expressed subtle changes, more drastic morphological shifts were documented in others. Moreover, the morphological changes that we observed tended to be associated with functional aspects of anatomy, ranging from head shape and organization, to the body length to depth ratio. These data suggest that native cichlid populations have undergone rapid (≤ 50 years), and in some instances dramatic, morphological changes since the closure of the dam, and provide insights as to the ways that different fish ecotypes may respond to sudden, large scale hydrological alterations.

2-4 GILBERT, AL*; MILES, DB; Ohio University; *anthony.gilbert09@gmail.com*

Thermoregulatory Behavior and Thermal Physiology are Evolutionarily Uncoupled in Phrynosomatid Lizards

Predicting organismal responses to environmental change requires understanding the proximate and ultimate causes for variation in important behavioral and physiological traits. Environmental and phylogenetic influences on behavior and physiology are likely to play important roles in shaping both phenotypic evolution and the responses of species to environmental change. However, the coevolution of behavior and physiology is rarely studied within both a phylogenetic and environmental context. Because of the evolutionary mismatch in the mode and rate at which behavior and physiology co-evolve, one would predict that behavioral and physiological traits exhibit unique evolutionary optima that might constrain rapid adaptation to environmental change. Here, we estimated thermal performance curves, thermal tolerance, and thermoregulatory behavior for Phrynosomatid lizards inhabiting the Sonoran Desert. Traits related to behavioral thermoregulation evolve much faster than thermal physiological traits, and behavioral traits evolve via Brownian Motion whereas all physiological traits exhibit some evolutionary optima. Thermal physiological traits exhibit much greater phylogenetic signal than do thermoregulation traits, and we found that environmental constraints are stronger on traits related to thermoregulatory behavior, and phylogenetic constraints are stronger on traits related to thermal physiology. When we modeled state-dependent shifts in thermoregulatory behavior, we found that no physiological trait influenced the evolution of thermoregulatory behavior. Theory predicts that behavior and physiology should coevolve in response to environmental variation. However, as environmental change selects for different combinations of behavioral and physiological traits, mismatches between these sets of traits can become exaggerated and result in novel phenotypic trajectories at multiple scales.

P3-161 GILCHRIST, SL*; RODRIGUEZ, L; GILCHRIST, Sandra; New College of Florida, Sarasota; *gilchrist@ncf.edu*

Trash or Treasure: Land Hermit Crab Use of Found Objects at Cayos Cochinos, Honduras

Hermit crabs are well known for their use of found objects such as shells. Some use other natural objects such as bamboo or other plant materials. The largest of the land hermit crabs (eg *Birgus latro*) abandon found objects as they become more terrestrialized. At Cayos Cochinos, we have recorded more use of plastics such as bottle tops, shot gun shells, lotion bottles, and similar objects over the past three years. As humans discard more of these materials, crabs of all sizes have incorporated the objects into their resource pool. We have enriched the area with a variety of shells over the past 14 years, also observing that the novel shells are readily used by the land crabs. The plasticity of use for the found objects poses an interesting question concerning resource acquisition and use, warranting further exploration on future expeditions.

P2-203 GILLIGAN, AM*; DILLON, JG; PERNET, B; ZIEGLER, A; California State Univ., Long Beach, Institut für Evolutionsbiologie und Ökologie, Rheinische Friedrich-Wilhelms-Universität; *ariel.gilligan@student.csulb.edu*

Characterization of the Microbial Community in a Recently Discovered Digestive Organ in the Heart Urchin Brisaster townsendi

Heart urchins (Echinoidea: Spatangoida) of the genus *Brisaster* are often abundant in deep water soft-sediment marine communities. They are deposit feeders and important bioturbators, but little is known of how these mud-dwellers process and digest food. Recently, a novel organ, the intestinal caecum, has been found in several spatangoid genera, but its physiological role is presently unknown. In *B. townsendi* (Agassiz, 1898), a heart urchin common in southern California, this organ is distinct from the rest of the gut in that it contains no sediment, but instead is filled with a dense microbial mass. We used next-generation sequencing to compare microbial communities in the stomach, intestine, intestinal caecum, and rectum of *B. townsendi* with the goal of understanding the caecum's role in the echinoid's biology. We collected *B. townsendi* from ~300 m depth off Long Beach, CA, and sampled the contents of each of the four gut regions from two specimens; in addition, the contents of the caecum were analyzed from an additional eight specimens. We extracted genomic DNA and amplified 16S rRNA genes using Illumina MiSeq. The results show that the caecum harbors a diverse community of anaerobic bacteria with large contributions from sulfate-reducing bacteria of Desulfobacterales averaging approximately 15.97% of the microbial community, as well as Spirochaetales (9.17%) and Bacteroidales (34.64%); this community is distinct from that of the rest of the gut. Using the relative abundance of microbial taxa within the different gut regions as well as additional data, a model for the role of the intestinal caecum in the digestive process of *B. townsendi* is presented.

P1-43 GILPIN, W*; PRAKASH, VN; PRAKASH, M; Stanford University; *wgilpin@stanford.edu*

Vortex Arrays and Chaotic Mixing by Swimming Starfish Larvae

Like many other invertebrates, starfish pass through a larval stage during which they are covered by ciliary bands. These bands facilitate simultaneous feeding and swimming as the animals navigate the oceanic environment, motivating the question of how hydrodynamic constraints govern the observed physiology and behavior of the larvae. We investigate this question using a combination of experimental fluid dynamics, and detailed theoretical modelling. We find that starfish larvae create localized ciliary reversal regions on their surface, which facilitate nutrient capture by drawing passing particles near the surface. Moreover, regular time variation in the ciliary beating allows the animal to replenish near-field regions depleted of nutrients, further increasing the animal's effective feeding rate. These findings suggest that by having cilia coupled to a nervous system, starfish and other invertebrate larvae are able to exhibit fluid dynamical behaviors that are unique among suspension-feeding microswimmers---suggesting that the ubiquity of ciliary bands among invertebrates may stem from their unique hydrodynamic properties.

P2-47 GINGRAS, MA*; EASTER, JH; RAMIREZ, MD; GOODHEART, JA; NEWCOMB, JM; New England College, University of Massachusetts, Amherst, University of California, Santa Barbara; *mgingras_ug@nec.edu*

R-opsin Localization in Dermal Extraocular Photoreceptors of Hermissenda opalescens and Berghia stephanieae

The nudibranch mollusk, *Hermissenda opalescens*, has been shown in previous experiments to have extraocular photoreceptors because of the presence of light-sensitive neurons located in the pedal ganglia. *Berghia stephanieae* is another nudibranch that is a promising organism for future studies of circadian rhythms and extraocular photoreception. The goals of this study were to: 1) identify the rhabodmeric opsin (r-opsin) sequence for *Hermissenda* and 2) to determine whether r-opsin is located in dermal and/or neural tissue in both *Hermissenda* and *Berghia*. Using bioinformatics, the *Hermissenda* r-opsin sequence was identified and alignment with orthologues in other species indicated that it contains the highly-conserved lysine residue involved in photopigment binding. This r-opsin sequence was used to develop complementary RNA probes for fluorescent *in situ* hybridization in *Hermissenda*. We also used a commercially available antibody raised again r-opsin in octopus, for immunohistochemistry in both nudibranchs. Regardless of the histological technique, r-opsin was localized in all of the integumentary structures investigated in both species, including the cerata, dorsal skin, oral tentacles, and the rhinophores. This dermal r-opsin localization was diffuse, as would be expected of extraocular photoreceptors. R-opsin was not present in the brain of either species. This evidence suggests that r-opsin may be used for dermal extraocular photoreception in both *Hermissenda* and *Berghia*.

P2-247 GLASGOW, S.; TROELSEN, P. V.; FALKINGHAM, P. L.*; MAREK, R. D.; Liverpool John Moores University, University of Liverpool; *p.l.falkingham@ljmu.ac.uk*

Stretching Evolution: Regionalisation and Neck Elongation in Plesiosaurs

Plesiosaurs are an extinct and iconic group of long necked marine reptiles from the Mesozoic. Neck elongation in plesiosaurs is almost unrivalled by both extinct and extant vertebrates, yet the mechanisms and selection pressures that underpin this elongation are poorly understood. Hox genes regulate axial regionalisation in vertebrates and the number of cervical regions is generally fixed within major groups of vertebrates. Recent work on cervical regionalisation in extant tetrapods has used 3D geometric morphometrics (GMM) as a proxy to delineate these regions governed by Hox gene suites, and has found that neck elongation in archosaurs occurs with the addition of regions beyond the basal number for amniotes; 3. We used 3D GMM and anatomical descriptions of plesiosaur cervical vertebrae in one species (*Muraenosauus leedsii*, R2863 BMNH) alongside comparisons to regionalisation within an extant phylogenetic bracket (archosaurs and squamates). Results from the GMM and comparative anatomical descriptions suggest that *M. leedsii* had 4 cervical regions. These regions consist of 1) the atlas-axis, 2) C3-C6, 3) C7-C37 and 4) C38-C42. These results suggest that *M. leedsii* had a derived regionalisation formula with the addition of a 4th cervical region, similar to modern archosaurs. Whilst our study so far entails only a single species of plesiosaur, our results suggest that plesiosaurs achieved such elongated necks predominantly by adding cervical vertebrae to region 3, rather than by changing Hox gene regulation to add more, novel, regions. A combination of further species included in this work flow, alongside a detailed examination of plesiosaur neck kinematics will allow for a more complete understanding of the role cervical regionalisation played in plesiosaur neck elongation.

18-5 GLON, H.*; DALY, M.; The Ohio State University; *Glon.2@osu.edu*

Cold-Water Connections: Systematics and Biogeography of the Sea Anemone Genus Metridium (Cnidaria: Actiniaria: Metridiidae)

Members of the sea anemone genus *Metridium*, are distributed throughout the cold-temperate Pacific and Atlantic Oceans. Included within this genus is the highly variable fluffy (or plumose) sea anemone, *M. senile*, which has the most extensive distribution, overlapping with every species within the genus. The high variation and plasticity in morphology paired with a lack of clear, distinguishable characteristics has resulted in taxonomic confusion within the genus, particularly in regard to *M. senile*. As genes evolve relatively slowly within cnidaria, traditional genetic markers have been unsuccessful at resolving relationships between both geographically distant and morphologically distinct individuals. We aim to elucidate relationships within this genus using genomic data to determine whether the most widely distributed species, *M. senile*, is truly a single, circumboreal species, and to compare deep water, larger individuals with smaller individuals found in shallower communities in the Pacific Ocean. Additionally, as there are several records of *M. senile* occurring in the southern hemisphere that are assumed to be relatively recently introduced, we also aim to determine a possible origin of these populations from the northern hemisphere. For this study, we sampled 76 individuals within *Metridium* across the distribution, inclusive of a southern site in Chile. We use data from produced using Restriction-site Associated DNA sequencing (RADseq) to build a maximum likelihood phylogeny and a species tree. These results substantially aid us in determining the status of *M. senile* as a single circumboreal species and uncovers a potential explanation for the presence of *M. senile* in the southern hemisphere.

P3-86 GLYNN, KJ*; ZAHOR, DL; CHIPARUS, CL; CORNELIUS, JM; Eastern Michigan University, Eastern Michigan University ; *kglynn2@emich.edu*

Body Condition and Feather Coloration of Urban Vs. Rural American Goldfinches (Spinus tristis) and American Robins (Turdus migratorius)

Many avian species live in both urban and rural environments, which can be beneficial or detrimental to the overall fitness of the residing population. Rural environments may offer a more natural setting with resources historically familiar to most species, whereas the urban environment may offer greater food predictability, protected nesting sites, and safety from some types of predators. Life in the urban environment may be detrimental to species or individuals that are not well adapted to living in close proximity to humans and infrastructure. Our study examined the health of urban and rural American Goldfinches, (*Spinus tristis*), and American Robins, (*Turdus migratorius*), by examining body condition and feather color. Both species obtain carotenoids to color their bright mating plumage from the environment and carotenoids also participate in anti-oxidant defense mechanisms. Brighter plumage may therefore reflect both environmental availability to carotenoids and/or higher individual condition or exposure to metabolic stress. Through this study we hope to better understand how these different habitats, and the potential trade-offs they offer, are impacting the health and overall fitness of these two species.

S9-8 GOCHFELD, DJ; Univ. of Mississippi; *gochfeld@olemiss.edu*

Phenotypic plasticity in chemical defense in sponges and corals

Many early metazoans use chemical defenses to protect themselves from biotic threats, such as predators, pathogens, and competitors. Production of secondary metabolites as chemical defenses is particularly important for the survival of sessile organisms that cannot escape these potentially life-threatening dangers. Sponges produce a tremendous diversity of secondary metabolites and are well known to rely heavily on chemical defenses for their protection. Factors that affect the production of these compounds are presumed to affect their function as well. Similar to sponges, corals also employ small metabolites for their defense, although these have not been as well studied as in sponges. Using metabolomics and bioassay approaches, we have characterized phenotypic plasticity in secondary metabolite production in sponges and corals in response to a variety of environmental and organismal factors, including geographic location, morphology, and disease state. In many cases, this plasticity translates into biological activity, providing protection against predators and pathogens. Sessile invertebrates, such as sponges and corals, rely on multiple compounds for protection from the suite of threats to which they may be exposed, and phenotypic plasticity provides a mechanism by which they can persist under varied environmental conditions.

P1-155 GODFREY, E*; MULLIN, S; LEESE, J; DeSales University; *eg8506@desales.edu*

The role of sexual selection in monogamy: exploring behavioral and hormonal mechanisms in a cichlid fish

In many monogamous species, both sexes compete for mates and demonstrate a preferential mate choice. However, the degree to which intrasexual competition limits the choice of the other sex is not well understood. Here, we explored how male-male competition influences female mate preference using a monogamous fish, the convict cichlid, *Amatitlania siquia*. Females observed a contest between two size-matched males until a winner and loser could be determined. Females were then given a choice between one of the individuals (winner or loser) and a novel individual that she had not previously interacted with. We hypothesized that females would prefer males that won contests and reject males that lost contests. In addition to exploring female preference after intrasexual competition, we investigated what role, if any, androgens might play in this process. Specifically, we measured 11-ketotestosterone (11-KT) before and after the male-male contest, as well as the female preference test using water-borne collection methods. Our results were unexpected; we found females showed no preference between winners or losers and novel males. We did find, however, that males preferred by females showed a drop in 11-KT levels. Taken together, these results suggest that females might not reject males that lose contests, and that androgen levels are more affected by female choice than male-male competition.

P3-166 GOESSLING, JM*; WARD, C; MENDONCA, MT; GOESSLING, Jeffre; Eckerd College, Auburn University Montgomery, Auburn University; *jeff.goessling@gmail.com*

Tradeoffs Between Acute and Chronic Thermal and Immune Acclimation in Common Musk Turtles Sternotherus odoratus

Understanding the role that thermal variability has in affecting immunity is key to understanding the causes and consequences of disease in ectothermic vertebrates. As turtles are exceptionally vulnerable to negative effects of global change, understanding the role of thermal environmental change is of specific importance to the group. Recent experimental studies have demonstrated that seasonal variability can directly account for changes in turtle immunity that may render populations more susceptible to disease. Further, studies have demonstrated that rapid temperature change may exacerbate the effects of seasonal change on turtle immunity. Herein, we performed several thermal and immune manipulations in common musk turtles (*Sternotherus odoratus*) to identify effects of both acute and chronic stimulation of the immune response, and how temperature affects this response. In acute temperature change experiments, we found that rapidly cooled turtles increased phagocytosis rate (P = 0.039) and bactericidal ability (P = 0.023) as compensatory acclimation for the reduced temperature. Similar compensatory acclimation was seen in turtles that were warmed, in which immune rates of production were slowed. In chronic experiments of immune stimulation (via lipopolysaccharide, LPS) and across two temperatures (25 and 30C), patterns were much less clear after 6 weeks of LPS administration, although warmer turtles generally followed the compensatory acclimation, similar to acutely stimulated turtles. Results from this study help shed light on the role of temperature in affecting immunity in ectotherms and the diversity of responses present within ectothermic groups.

P2-130.5 GOETZ, SM; PICCOLOMINI, S; HOFFMAN, M; BOGAN, J; HOLDING, ML; MENDONCA, MT*; STEEN, DA; Auburn Univ., Central Florida Zoo & Botanical Gardens, Central Florida Zoo & Botanical Gardens, Florida State University, Georgia Sea Turtle Center, Jekyll Island Authority; *mendonca@auburn.edu*

Serum-based Inhibition of Pitviper Venom by Eastern Indigo Snakes

When organisms possess chemical defenses, their predators may eventually evolve resistance to their toxins. Eastern Indigo Snakes (*Drymarchon couperi*; EIS) subdue and consume a variety of pitviper species and it has been suggested EIS possess a physiological resistance to their venom. In this study, we formally investigated this hypothesis by using microassays that measured the ability of EIS blood sera to inhibit A) hemolytic and B) snake venom metalloproteinase (SVMP) activity of Copperhead (*Agkistrodon contortrix*) venom. To serve as controls, we also tested the inhibitory ability of sera from inbred House Mice (*Mus musculus*) and from a snake that does not feed on pitvipers, the Checkered Gartersnake (*Thamnophis marcianus*). As expected, mouse sera exhibited little effect on the activity of either class of toxins tested. However, sera from both EIS and gartersnakes inhibited over 60% of SVMP activity. EIS sera also inhibited 78% of venom hemolytic activity, while gartersnake sera failed to inhibit these toxins. Our results demonstrate that EIS serum is indeed capable of inhibiting two of the primary classes of toxins found in Copperhead venom, suggesting that EIS may possess physiological resistance to venom upon injection. Because we documented resistance to hemolytic components of pitviper venom within EIS but not gartersnakes, we speculate this resistance may be driven by antagonistic interaction while resistance to SVMP may be relatively widespread among snakes and not necessarily related to the diet and ecology of extant species.

35-1 GOFF, CB; Texas State University; *goff@txstate.edu*

Higher Water Temperatures Lower Physiological Health in Leopard Frog Tadpoles

Climate change is expected to increase temperatures and drought frequency which can combine with direct threats such as urbanization to alter habitat quality such as canopy cover. Together these factors can affect overall health and survival of individuals, disrupting homeostasis, development, and immune responses, which increase the susceptibility of populations to declines. In response to stressors, vertebrates release glucocorticoids (GC) that assist in energy mobilization, mediate natural changes in physiology and behavior, and help return the organism to homeostasis. Amphibians are particularly susceptible to changes in environmental conditions, releasing the GC hormone corticosterone (CORT) in response to stressors, including increased temperatures. Increased temperatures also result in faster metamorphosis, but reduced body size and lower survival. I tested the hypothesis that higher water temperatures affect physiological health in tadpoles. I set up a laboratory experiment manipulating water temperatures using tank heaters (19C vs 27C) and manipulated canopy in outdoor mesocosms with shade cloth or open canopy. To assess physiological health, I examined water-borne CORT release rates, development, and mucosome function of Rio Grande leopard frog (*Rana berlandieri*) tadpoles. Mucosome function is the ability of the skin secretions and microbiotic community to fight a known pathogen. Increased water temperatures raised CORT release rates in lab-reared tadpoles. Tadpoles developed faster in open canopy but had lower survival, while CORT release rates and mucosome function differed between treatments. This research examines a robust suite of physiological metrics and indicates increased water temperatures from modified habitat and climate change can have multiple negative impacts on developing amphibians.

P1-107 GOGEL, CA*; MULLIN, SM; LEESE, JM; DeSales University; *cg3612@desales.edu*

House Hunters: Cichlid Edition - Females in a monogamous pair determine nest site location

For territorial animals, one of the most important decisions faced during their lifetime is determining where to establish a territory. This is especially true when a territory includes a breeding substrate or nest site. For many taxa, decisions about territory sites are made individually, but for monogamous species, a pair-bond may form prior to a territory and nest site being selected. Here, we explored which sex might be more likely to choose a nest site using a monogamous fish, the convict cichlid, Amatitlania siquia. In nature, little is known regarding how and when convict cichlids choose nest sites, but studies suggest a combination of strategies in which either the male selects the nest site before courting females or the pair selects a site together. Based on this, we hypothesized that males are more likely to determine a nest site, even after a pair-bond has formed. We tested this hypothesis by observing pair-bond formation, then after a pair-bond formed, we placed males and females in separate compartments of a divided aquarium with their own nest site. After 24 hours, the divider was removed, and the location of both individuals in the aquarium was observed for several days. Overall, females seemed to stay with the nest site they were acclimated to and the males showed less preference, in many cases moving to the female side. These results suggest that the female, rather than the male, may be more likely to choose both territory and nest site after pair-bond formation in this system. While unexpected, this result could indicate that females have been selected to be more discerning of nest sites as they require smooth surfaces to deposit their eggs.

81-4 GOLDSMITH, H; DALEY, MA*; Royal Veterinary College; *mdaley@rvc.ac.uk*

Dynamics of turning maneuvers on high and low friction terrain in helmeted guinea fowl (Numida meleagris)

To move through natural environments, animals must balance many potential performance demands, including speed, economy, agility, stability and injury risk. Speed and stability during turning maneuvers are important performance demands when evading predators or avoiding collisions/falls. We have investigated locomotor dynamics during turning maneuvers in the helmeted guinea fowl (*Numida meleagris*). To manipulate locomotor priorities evident during turning, we compared turning maneuvers on high versus low friction terrain. Turning maneuvers were executed in a 90-degree bent runway that was wide enough to allow variation in turn sharpness as a control strategy. We expected low friction terrain to cause a shift in priorities to minimize horizontal forces for slip avoidance, leading to slower speeds, shorter step lengths and a shallower turn angle (closer to bend-running) on slippery terrain. Overall, we found that guinea fowl used surprisingly similar turn strategies in both high and low friction terrains, opting for a relatively shallow turn angle in both conditions. This suggests peak load regulation is a priority in both conditions. Average running speeds were slower approaching turns compared to straight runs on both substrates. Low friction terrain increased the frequency of slips and falls, yet, despite this, led to relatively subtle changes in turn strategy compared to high friction terrain. Birds did exhibit a significant learning effect over repeated trials. With practice, birds learned to maintain higher speed during turns on the high friction substrate but continued to slow down in approaching the turn on slippery substrates. The findings suggest that guinea fowl shift their locomotor priorities with experience on varied terrain conditions. Further research is needed to understand how locomotor control is adjusted over different timescales and varied levels of experience in diverse environments.

P1-36 GONG, Z*; JAFFE, NH; BLAND, R; COHEN, CS; EOS, SFSU; Univ. of California, Berkeley, EOS, SFSU; *lauragong@berkeley.edu*

Who is Stronger: Attachment Strength of Leptasterias spp. in Relation to Microhabitats and Clades

Intertidal areas are highly variable environments imposing selective forces unevenly on organisms, potentially leading to divergence in behavior and morphology in closely related taxa. *Leptasterias* is a species complex of small, direct-developing sea stars living across intertidal habitats and experiencing different degrees of abiotic stresses, including wave impacts. We compared attachment strength and mobility in *Leptasterias* spp. from microhabitats inferred to be more or less wave-impacted. Attachment strength, the force required to dislodge a star from its substrate, was quantified by a direct pulling test in field and laboratory using a flexible, piano-wire clamp connected to a spring scale. Additionally, resistance to dislodgement by controlled water surge was measured in field and lab environments. And, righting time of sea stars placed oral side up ("flip time") was recorded as a measure of mobility, in the field and lab. We analyzed results of these tests using Mann-Whitney U tests and showed that the attachment strength of *Leptasterias* spp. in more wave-impacted microhabitats is greater than in less wave-impacted microhabitats, whereas the mobility of more wave-impacted sea stars was lower than that of less wave-impacted sea stars. The difference in attachment strength and mobility of *Leptasterias* spp. may be a local adaptation to wave-stressed environments and is being further explored using genetic methods.

P3-111 GONZALEZ, A*; OCHRIETOR, J; AHEARN, G; University of North Florida; *gahearn@unf.edu*

Molecular Characterization of a Novel Disaccharide Transport Protein in Homarus americanus

Essential sugar absorption in animals has been demonstrated to occur by cleavage of polysaccharides into their monomeric form for transport across epithelial cells of the gastrointestinal tract. Recently, it has been suggested that the hepatopancreas of the American lobster, *Homarus americanus*, transports intact disaccharides across their epithelial cells. The purpose of the present study is to better assess the genetic characteristics of this novel transport mechanism by cloning the cDNA encoding the transport protein and determining its location of expression. To accomplish this goal, cDNA generated from adult male lobster hepatopancreas RNA and cDNA from a constructed library was used for PCR cloning. Additionally, *in situ* hybridization and quantitative RT-PCR were performed to localize the expression of transporter cDNA in the hepatopancreas and other tissues thought to utilize this transport mechanism. The partial DNA sequence that was obtained is homologous to a disaccharide transporter in *Drosophila melanogaster*. The analyses from *in situ* hybridization and q-RT-PCR suggest the expression of the transporter in various tissues, especially those related to digestion and absorption (hepatopancreas and intestine). These tentative results provide a foundation upon which the complete molecular characterization and organ distribution of this novel disaccharide transporter will be described.

P3-183 GONZALEZ, P*; CHRYSOSTOMOU , E; FLICI , H; GAHAN , JM; SCHNITZLER, CE; FRANK , U; BAXEVANIS , AD; NHGRI/NIH, NUI Galway, U. Florida; *paul.gonzalez@nih.gov*

From Stem Cell to Neuron: Transcriptional Profiling of Differentiating Neurons in the Cnidarian Hydractinia

Hydractinia symbiolongicarpus, a colonial hydrozoan cnidarian, is a proven and tractable model for studying regeneration and stem cell biology. Its adult tissues contain stem cells called interstitial cells (or i-cells) that are responsible for their ability to regenerate after injury and to continuously renew somatic cells during normal homeostasis. Depending on their cellular context, i-cells have the ability to differentiate into several types of epithelial, neural, or germ line cells. However, the molecular mechanisms that regulate these developmental decisions and the transcriptional changes experienced by i-cells as they commit to different fates are largely unknown. In this study, we characterized the transcriptional profiles of i-cells at different stages of neurogenesis in adult feeding polyps. We performed fluorescence-activated cell sorting (FACS) using transgenic animals expressing reporters for key markers of specific stages in the neurogenic pathway, followed by RNA-seq differential expression analysis. We report full transcriptomes for *Piwi1*-expressing i-cells, *SoxB2*-expressing neural progenitors, and two subtypes of differentiated *RFamide*-expressing neurons. Current work is focused on identifying new cell type-specific markers, as well as candidate genes and signaling pathways involved in cell fate determination. These data provide the first characterization of the transcriptional repertoire of *Hydractinia* i-cells and their progeny, identifying specific targets for future functional studies. Understanding the mechanisms underlying the choice of i-cell trajectory may ultimately allow us to harness these mechanisms to identify new targets for therapies in regenerative medicine.

78-3 GOODCHILD, CG*; WOMBLE, B; GRINDSTAFF, JL; DURANT, SE; Oklahoma State University, University of Arkansas; *christopher.goodchild@okstate.edu*

A novel approach to measuring oxidative stress in avian red blood cells links heme degradation to senescence

Understanding the interactions between aging, oxidative stress, and altered red blood cell (RBC) physiology remains a challenge due to the complexity of the antioxidant defense system and numerous potential target sites of oxidizing agents. Here, we investigated the relationship between RBC damage and aging by developing a new approach to measuring oxidative stress. Using a series of *in vitro* and *in vivo* procedures, we systematically explored (1) whether avian RBCs generate fluorescent heme degradation products (HDPs), (2) whether HDPs interact with RBC membranes, (3) whether HDPs are linked to impaired RBC integrity, and (4) whether aging is associated with elevated HDPs. Using zebra finches (*Taeniopygia guttata*), we found that avian RBCs exposed *in vitro* to hydrogen peroxide had a dose-response increase in fluorescent HDPs and that HDPs associated with RBC membranes. Moreover, *in vitro* exposure to hydrogen peroxide caused a 25% reduction in relative hemoglobin and converted 95% of hemoglobin to non-oxygen binding methemoglobin, further indicating hemoglobin degradation. In addition, elevated HDP fluorescence was associated with decreased membrane integrity and increased erythrocyte osmotic fragility *in vivo*. To examine the relationship between HDPs and aging, we collected RBCs from zebra fiches of known ages (600-2300 days old) and found a positive correlation between HDPs and age. This study is the first to demonstrate HDP fluorescence in a non-mammalian system, and suggests HDPs may be a useful tool for measuring oxidative stress and understanding the aging process.

50-2 GOODHEART, JA*; COLLINS, AG; CUMMINGS, MP; RAWLINSON, KA; Univ. of California, Santa Barbara, Univ. of Maryland, College Park, Smithsonian Institution, Univ. of Cambridge; *goodheart@ucsb.edu*

Using RNA-Seq to elucidate the phylogeny of Polycladida (Platyhelminthes), a flatworm clade with diverse life histories

Flatworms are among the most diverse invertebrate phyla, with over 100,000 parasitic and free-living species. Polycladida, an order of predatory marine flatworms, exhibits direct, intermediate, and indirect development and a diversity of larval morphologies. Because life history strategies are important components of fitness, understanding the evolution of modes of development can help us comprehend the complexities of adaptation. Polycladida has traditionally been divided into two sub-orders based on, in part, the presence (Cotylea, ~350 species) or absence (Acotylea, ~450 species) of a ventral adhesive structure. Due to morphological homogeneity and insufficient molecular data, deep divergences among taxa within this order remain poorly understood. To improve phylogeny inference for this clade, we generated RNA-Seq data for 20 species of polyclads and combined these data with transcriptomes from fifteen additional in- and out-group taxa from the NCBI for phylogeneny inference. We next reconstructed ancestral life history characters among the lineages in our tree to discern where particular development modes and larval forms originated. Our results provide a well-supported preliminary hypothesis for early divergences within Polycladida, including support for the two sub-orders Cotylea and Acotylea. Further, this phylogenetic hypothesis indicates that taxa from Cotylea, and many from Acoylea, possess indirect development (although with different larval forms). However, there appears to be a transition to direct development with Acotylea. This work represents an important step in our comprehension of life history evolution among free-living flatworm clades.

P1-292 GORDON, KE*; MCCOY, MW; East Carolina University; *gordonka17@students.ecu.edu*

How Temperature, Resource Input, and Standing Genetic Variation Affect Predator Responses of Physa acuta

Changes in the environment influence ecosystems by reducing the suitability of habitats for species and by altering the strength of interspecific interactions. Both pathways change ecosystems via top-down and bottom-up processes. Temperature and external nutrients in aquatic systems effect primary production rates, and thus the growth rates of primary consumers, as well as the vulnerability of consumers to predation. Genetic variation of individuals influences such processes. In this study, we test how temperature, nutrient availability and standing genetic variation of *Physa acuta* affects the snail's growth and vulnerability to predation by *Procambarus clarkii*. We reared snails from inbred or outcrossed lineages at high or low temperatures, with high or low resource inputs and with or without chemical cues of crayfish predation. We assessed how these treatments affected predator avoidance behavior, antipredator morphological responses, reproductive output and survival. While we found little difference in the behavioral response between treatments, we found differences in growth rates in response to resource input, standing genetic variation and temperature. Snails from outcrossed lineages were larger than inbred snails across treatments and snails only produced eggs at the lowest temperatures with the highest resource input. More eggs were laid by snails exposed to predator cues. At high temperatures, survival was reduced across treatments. We found that combined effects of resource input and temperature on growth rates influences rates of predation by crayfish, due to size dependent vulnerability. These results indicate that changes in the environment have effects on species interactions in ways that cascade through food webs and potentially change ecosystem functions.

108-2 GORMALLY, BMG*; ESTRADA, R; YIN, H; ROMERO, LM; Tufts Univ.; *brenna.gormally@tufts.edu*

Recovery periods during chronic stress exert complex physiological and behavioral changes in house sparrows

Chronic stress has been extensively studied in both the laboratory and field. What remains unknown is whether and how recovery periods between episodes of chronic stress influence these responses. This is a crucial question because animals are often exposed to chronic stress and it's important to understand if the effects of these situations can be alleviated. To test this, we exposed house sparrows (*Passer domesticus*) to two bouts of a chronic stress protocol that consisted of random, repeated stressors. Birds were assigned to treatment groups that differed in the amount of recovery time between the two sets of chronic stress—0 hours, 24 hours, 72 hours, or 144 hours. Blood samples and video recordings were taken before the experiment, before and after the recovery periods, and after the second bout of chronic stress. Video analysis assessed changes in perch hopping activity. Blood samples assessed changes in baseline and stress-induced corticosterone (Cort), Cort negative feedback strength, immune function, and uric acid concentrations. We found no significant differences in any recovery group in baseline or stress-induced Cort, but birds failed to shut down the release of Cort after receiving 24 hours of recovery. While recovery length did not affect uric acid concentrations, chronic stress tended to increase it. Bacterial killing capacity decreased in birds that received 0, 72, or 144 hours, but remained the same in birds that recovered for 24 hours. Finally, perch hopping tended to increase during the first round of stressors and decrease in the second round of stressors. These data suggest that recovery periods do influence physiology and behavior, but don't necessarily "reset" the animals.

P3-62 GORVET, MA; AVEY-ARROYO, JA; BUTCHER, MT*; Youngstown State University, The Sloth Sanctuary of Costa Rica; *mtbutcher@ysu.edu*

Keep Calm and Hang On: EMG Activation Intensity in the Forelimb of Three-toed Sloths

Sloths exhibit below branch locomotion and postures whereby fore- and hindlimb pairs equally support their body weight. Suspensory habits require both strength and fatigue resistance of the limb flexors, yet muscle mass is reduced in sloths. It is then possible that sloths minimize muscle activation during tensile loading of muscle-tendon units to maintain support, thus indicating potential neuromuscular specializations for conserving energy. Electromyography (EMG) was evaluated in three-toed sloths (*Bradypus variegatus*: *N*=6) to test this hypothesis. EMG was recorded (2000Hz) via fire-wire electrodes implanted into 8 forelimb muscles while sloths performed suspensory hanging and walking, and vertical climbing. Video recordings (100Hz) were synchronized with EMG to mark footfalls for a total of 227 strides analyzed. EMG activation for each muscle was normalized to peak activation recorded across behaviors. *B. variegatus* demonstrates that flexor/extensor muscles are minimally activated during hanging. Compared to hanging, EMG activation in the forelimb flexors doubles during suspensory walking and increases by a factor of 1.3 during vertical climbing. Overall, the elbow flexors mm. biceps brachii and brachioradialis show the greatest EMG activation, and these large bursts occurred during suspensory walking, while burst intensity was more similar (within 5-15%) between walking and climbing for the m. pectoralis superficialis, biarticular m. triceps brachii long head, and the digital extensors. Activation of the elbow flexors, in particular, may be critical for stabilizing forces acting on the forelimbs during suspension. Further evaluations will include assessment of recruitment frequencies of slow and fast motor units using wavelet analysis.

S8-4 GOSWAMI, A*; WATANABE, A; FELICE, RN; BARDUA, C; FABRE, A-C; POLLY, PD; Natural History Museum, London, New York Institute of Technology College of Osteopathic Medicine, University College London, University College London, Natural History Museum, Indiana University, Bloomington; *a.goswami@nhm.ac.uk*

Phenomic approaches to analysing integration in complex systems and across diverse taxa: the good, the bad, and the ugly

Approaches for quantifying form to assess phenotypic integration vary from linear measurements to high-density surface geometric morphometrics, and each has strengths and weaknesses. High-dimensional approaches better capture shape, particularly for complex structures, and allow more robust comparisons across disparate taxa, which may share few Type 1 landmarks. However, high-density geometric morphometric approaches also bring challenges, e.g., with dimensionality and possible statistical artefacts imposed by Procrustes superimposition. Here, we present simulations and four case studies spanning 730 species of squamates, birds, salamanders, and caecilians that exemplify the promise and diverse challenges of high-dimensional analyses of integration. We assess: 1) does Procrustes superimposition affect analyses of modularity?; 2) is big data actually better?; and 3) how do analyses of integration with high-dimensional semilandmarks compare to those with only landmarks? Procrustes superimposition can mask modularity, especially when the number of landmarks is low (e.g., < 15) and they covary in parallel directions, but the effect decreases with increasing landmark number or more complex modular covariance patterns. Landmark Sampling Evaluation Curve analyses demonstrate that for many skull regions 20-30 landmarks/semilandmarks are needed to accurately characterize shape, and landmark-only analyses do a particularly poor job in vault and rostrum bones. Full, subsampled, and landmark-only analyses of integration are generally congruent, but landmark-only analyses show higher integration between adjacent bones in which landmarks are generally limited to the sutures of those bones.

115-6 GOUGH, WT*; SEGRE, PS; CADE, DE; FISH, FE; KENNEDY, JH; SIENKIEWICZ, R; POTVIN, J; GOLDBOGEN, JA; Stanford University, West Chester University, Saint Louis University; *wgough@stanford.edu*

Comparative Kinematics and Hydrodynamics of Mysticete Cetaceans: Morphological and Ecological Correlates with Swimming Performance

The scale-dependence of locomotor performance has long been studied in comparative biomechanics, but how animals move in their natural environment remains poorly understood. At the upper extreme of body mass, baleen whales (Mysteci) are predictably among the most efficient swimmers in terms of cost of transport through a combination of low mass-specific metabolic rate and high hydrodynamic efficiency. Such efficiency enables these oceanic giants to migrate vast distances and thus underlies a major component of their life history and functional ecology. However, we lack even basic kinematic data for most species. Here we combine morphometric data from flyover drone photography, whale-borne inertial sensing tag data, and computational fluid dynamics (CFD) to study the locomotion of four rorqual species. Focusing on fundamental kinematic parameters such as tailbeat frequency and forward speed, we quantified spatial and temporal changes in swimming performance for individual whales and compared these metrics across a wide body mass range. We also calculated thrust and drag using lunate tail hydrodynamic modeling (Fish 1993), and compared these values against those from CFD simulations carried out with realistic rigid-body models. Differences in excess of 100% between the two approaches point to the significant contributions of tail and head heaving to overall drag, and thus the need to account for them in rigid-body CFD simulations. Together these kinematic data and CFD modeling inform a new parametric factor designed at multiplying the rigid-body drag equation to predict the contribution of body heaving unsteady hydrodynamics in cetaceans.

14-2 GOYES VALLEJOS, J*; GRAFE, TU; WELLS, KD; University of Connecticut, University of Kansas, Universiti Brunei Darussalam, University of Connecticut, University of Kansas; *goyes.johana@gmail.com*

Don't Put All Your Tadpoles In One Basket —Parental Strategies In A Frog With Larval Transport

Parents have evolved a variety of strategies to minimize risks to their offspring, choosing rearing sites based on different abiotic and biotic factors, which affect offspring survival. Because availability and quality of these sites are variable, parents may have to choose between low-quality rearing sites or extended search time. In frog species with larval transport, parents are known to select bodies of water that are free of predators, or intra and/or interspecific competitors. We experimentally tested if abiotic factors and/or the presence of predators and conspecifics affect tadpole deposition behavior in a population of the Smooth Guardian frog of Borneo *Limnonectes palavanensis*. This species lays its eggs on land and guards them until they hatch; tadpoles are then transported on the male's back to small pools of water on the forest floor. We estimated the abundance of natural tadpole rearing sites and conducted experiments in the field using artificial pools to test if abiotic characteristics of these pools affect the probability of larval deposition. We also experimentally tested whether males of *L. palavanensis* avoid pools with conspecific tadpoles or predators. The abundance of natural deposition sites was low, and males readily used artificial pools for tadpole deposition. Males were less likely to deposit tadpoles in areas were pool permanency was compromised. Males did not avoid depositing tadpoles in pools with conspecifics or with predators. Interestingly, males exhibited clutch-partitioning behavior, dividing tadpoles between adjacent pools. Pool availability, rather than the presence of potential competitors or predators may be the main factor affecting parental decisions in this species.

78-4 GRACE, JK*; ANDERSON, DJ; ANGELIER, F; Texas A&M University, Wake Forest University, Centre d'Etudes Biologiques de Chize, CNRS, Texas A&M University, Department of Wildlife and Fisheries; *jkgrace@tamu.edu*

Long-term Effects of Early-life Stress on the HPA Axis in a Short- and Long-lived Bird

Acute, short-term effects of early-life stressor experience and associated glucocorticoid upregulation on physiology and survival are widely documented across vertebrates. However, long-term effects of early-life stress are less well understood, especially for wild species through adulthood. We evaluate effects of early-life stress on baseline and stress-induced corticosterone in two wild birds: free-living Nazca boobies (*Sula granti*) and captive House sparrows (*Passer domesticus*). Nazca booby adults that experienced maltreatment as nestlings, a wholly natural stressor, exhibited depressed baseline corticosterone in females, and elevated stress-induced corticosterone in males. House sparrow adults that experienced an experimental increase in circulating corticosterone as nestlings also displayed depressed baseline corticosterone , and in contrast to Nazca boobies, depressed stress-induced corticosterone. These results highlight the sex- and species-specific nature of long-term effects of early-life stressor experience. We discuss these results within the context of life history and fitness consequences of altered HPA axis activity.

P2-169 GRAHAM, AM*; BARRETO, FS; Oregon State University; *grahaall@oregonstate.edu*

Interpopulation Variation of Hypoxia Tolerance in an Intertidal Copepod, Tigriopus californicus

Environmental variation along a species' geographic range often imposes strong selection on isolated populations. In the absence of gene flow, populations may become locally adapted, which facilitates population divergence, and potentially speciation. Natural systems in which genetically divergent populations have adapted to different levels of environmental stress allow us to examine the relevance of genetic variation for adaptive evolution of gene networks. Most intertidal organisms experience short-term changes in abiotic factors including temperature, salinity, and dissolved oxygen (DO) in their marine or estuarine habitats. Previous work has shown that *T. californicus* can withstand prolonged exposure to extreme oxygen deprivation with very little mortality; however, this was assessed in only one population, and it is unknown to what degree allopatric populations along a wide latitudinal range are similarly tolerant. Here, we assess both juvenile and adult response to extreme hypoxia in multiple populations of *T. californicus* from California to Oregon. Ultimately, we show evidence for population-level variation in tolerance to low DO levels with regards to survival, as well as growth and development.

89-7 GRAHAM, AM*; BARRETO, FS; Oregon State University; *grahaall@oregonstate.edu*

In Search of Alternative Molecular Mechanisms Underlying the Transcriptional Response to Hypoxia, in an Organism Without the Hypoxia Inducible Factor (HIF) Pathway

To maintain homeostasis, multicellular eukaryotes have evolved tight coordination of numerous genes that control specialized mechanisms to enhance O_2 uptake and distribution, resulting in dynamic respiratory and circulatory systems, capable of responding to changes in O_2 availability. Environmental stressors such as changes in temperature, salinity, and pH are well-studied in intertidal systems, but hypoxia is often overlooked, even though it is an important physiological threat in marine habitats. In this study, we test the ability of the intertidal copepod *Tigriopus californicus* to withstand low-oxygen conditions for extended periods of time, as well as the impact of hypoxia on developmental time points and survival. We also assay the transcriptional response of *T. californicus* to hypoxia stress over acute and chronic exposure times, by utilizing RNA-seq to determine which genes/pathways are involved. Ultimately, we show that *T. californicus* can withstand prolonged exposure to extreme oxygen deprivation with little to no mortality in adults, and no significant change in development in larvae/juveniles. In addition, we show that *T. californicus* has secondarily lost key HIF-pathway members, and that the transcriptional response to hypoxic stress has been off-loaded to (or co-opted by) other mechanisms, including genes involved in cuticle reorganization and ecdysis, as well as mitochondrially embedded/localized genes associated with pathways of oxidative stress.

10-6 GRANATOSKY, M/C*; ROSS, C/F; Univ. of Chicago; *michael.granatosky@gmail.com*

Variation in Proprioceptive Sensory Systems across Tetrapods Demonstrate Performance Consequences During an Unexpected Fall

In natural environments, animals must negotiate variable terrain and recover from unexpected perturbations. At present, we know little about the control strategies that animals use in the face of perturbations, but proprioceptive feedback from muscle spindles and golgi tendon organs plausibly play a role in helping animals maintain stability and prevent catastrophic falls. Interestingly, birds and mammals have convergently evolved derived proprioceptive sensory systems compared to other tetrapods. The functional consequences of this variation in proprioceptive sensory systems remain unknown, but it is possible that birds and mammals may be better equipped than other tetrapods to maintain dynamic stability during an unexpected perturbation. In this study, we perturb the running of tufted capuchin monkeys and Savannah monitors with an unexpected drop in substrate height. From these trials, we assess the extent that animals maintain body weight support and spring-like body dynamics in the perturbed step. We compare these data to previously published trials collected from guinea fowl. Our results demonstrate that, despite a great deal of variability in the response, birds and mammals are quite successful in maintaining dynamic stability. The response strategies used by birds and mammals occur across a continuum with varying degrees of body weight support and actuation by the limb related to the magnitude and direction of the ground reaction force impulse. In contrast, during an unexpected fall Savannah monitors stumbled more frequently and revealed no predictable response strategy for maintaining stability based on patterns of ground reaction force impulse. Taken together, these results demonstrate performance consequences associated with differing proprioceptive sensory systems in tetrapods.

P2-109 GRANT, AR*; MALISCH, JL; KIMBALL, MG; OUYANG, JQ; University of Nevada, Reno, St. Mary's College of Maryland; *averygrant@nevada.unr.edu*

Glucocorticoid physiology, territory size, and number of chicks fledged: Untangling the relationship between corticosterone and reproductive success

Breeding is an energetically expensive life history stage, particularly for short-lived organisms inhabiting highly variable environments. Corticosterone (cort), a glucocorticoid hormone, is released in response to noxious and unpredictable stimuli but also acts to increase metabolism at baseline levels. Successful individuals need to balance energy expenditure and costs to maximize fitness. However, evidence for a clear relationship between cort and fitness is lacking, complicated by the fact that this relationship can change within and between life-history stages. We collected repeated within-individual baseline and stress-induced plasma and feather cort levels using free-living mountain white-crowned sparrows (*Zonotrichia leucophrys oriantha*) from pre-breeding to post-breeding during variable environments. Additionally, we mapped territory size for breeding pairs using telemetry and collected data on reproductive success. Using nest cameras during incubation through fledging, we also measured reproductive effort. We discuss the link between the cort phenotype, territory size, and reproduction. These repeated measures data add to the growing research on understanding how flexible cort phenotypes act in changing environments.

39-6 GRAY, WA; SUNNUCKS, E; HUBER, T; ZIMMERMAN, LM*; Millikin University, Towson University; *lmzimmerman@millikin.edu*

Natural Antibody Abundance But Not Avidity Predicts Salmonella Infection in a Reptile

Salmonella is a generalist pathogen prominently found in various taxa including reptiles, birds, and mammals. While mammals and birds face severe symptoms from *Salmonella* infection, reptiles are typically able to tolerate the colonization with no associated disease. Further, despite the lack of symptoms, reptiles are still able to transfer the infection to other organisms. Recent studies in turtles suggest that natural antibodies (NAbs) play a role in parasite defense; however, it is unknown the role NAbs may play in *Salmonella* infection and tolerance in reptiles. Plasma and mucosal samples were taken from red-eared slider turtles. We measured levels and avidity of antibodies that bound to lipopolysaccharide (LPS), a component of *Salmonella* cell wall. We examined the relationship between these measures and the ability of plasma to kill Salmonella as well as infection status. Higher mucosal antibody levels to LPS were significantly associated with a decrease in likelihood of infection with *Salmonella*; however, plasma antibody levels were not. Killing capacity of the plasma was significantly related to plasma antibody levels to LPS, but not mucosal antibody levels. Avidity was not significantly related to either killing capacity or likelihood of infection. Our results add further evidence that turtles use a general, nonspecific NAb response to combat pathogens.

P1-167 GRAY, CS*; PHILSON, CS; FOLTZ, SL; DAVIS, JE; Radford University; *cgray34@radford.edu*

PASSER: Utilizing Neural Networks during Data Collection for Real-time Bird Identification

Field-based research projects utilizing automated image capture devices often rely on humans to identify images. This method of analysis is limited in that data can only be retroactively parsed by an observer looking to identify patterns in behavior. If birds could be identified in real-time by an automated process integrated into the camera device, not only would there be hours of time saved identifying animals, it would also enable the possibility of a varied response to different subjects at the time of data collection. We accomplished exactly this as part of the PASSER program by use of Tensor Flow, a neural networking package for the programming language Python that allows users to create a neural network for image classification. A neural network requires a large repository of photos when being used for image classification so that it can provide more accurate identification of the images it will be given. The PASSER project has collected hundreds of thousands of photos of various bird species to be fed into the neural network so that it can fine tune its "neurons" for identification of various species and sexes. The smart feeder can then be updated to use the neural network on its own so that the system sustains itself without human interaction other than necessary hardware maintenance. The neural network, with enough collected data, could potentially even be used to identify individual birds if that specific individual bird frequents the feeder sufficiently often. The uses for this data are abundant as patterns could be easily localized and analyzed without the necessity of countless man hours spent identifying birds. Processes like these may enable a shift of focus from simple species identification, into broad-based environmental-ethological analysis.

57-5 GRAYSON, P*; YOUNG, JJ; EDWARDS, SV; TABIN, CJ; Harvard University, MCZ, Harvard Medical School, Genetics; *pgrayson@fas.harvard.edu*

Convergent Regulatory Evolution and Forelimb Heterochrony in Flightless Birds

Palaeognathae, the avian clade comprising the flightless ratites, such as the emu (*Dromaius novaehollandiae*) and ostrich (*Struthio camelus*), alongside their volant (flight capable) relatives the tinamous, provides a unique setting to study both phenotypic and genomic aspects of repeated loss of a complex trait; a minimum of three convergent losses of flight are inferred within the group. The ratites exhibit the phenotypes most commonly associated with flightless birds, including reduced wings, whereas the tinamous have retained flight-associated traits. We find that in contrast to ratite embryos, the forelimb of the Chilean tinamou (*Nothoprocta perdicaria*) does not experience a delay in early development compared to the hindlimb. This suggests that ratite forelimb heterochrony results from selective relaxation for, or selection against, the early development of robust wings. The most extreme heterochony in ratite forelimb development is seen in the emu. We identified down-regulation of SALL1 in the emu forelimb at stage HH18 compared to the emu hindlimb, and both limbs of chicken (*Gallus gallus*) using RNA-seq. Comparative ATAC-seq on HH18 limbs and flank mesoderm identified an enhancer near SALL1 that is active in proliferating limbs, but inactive in non-proliferative mesoderm (both flanks and the emu forelimb). To examine whether convergent forelimb heterochrony in ratites is determined by similar gene expression and regulatory changes across the palaeognath tree, we are analyzing stage-matched RNA- and ATAC-seq for forelimb and hindlimb at HH18 and HH25 in the Chilean tinamou, ostrich, greater rhea (*Rhea americana*), emu and chicken. Our results thus far suggest that heterochronic shifts in flightless birds are driven in part by changes in enhancer activity and accessibility to transcription factors.

56-1 GRECO, G*; EVERT, B; JUDGE, T; MAYVILLE, F; SLEE, J; DeSales University; *gg1724@desales.edu*

Wine your way to good health: Anti-Inflammatory Effects of Resveratrol

Resveratrol, an antioxidant found in red wine and grapes, is thought to possess anti-inflammatory properties in relation to cardiovascular disease, and may have beneficial effects on incisional wound healing and the body's response to biomaterials. Liquid-liquid extraction of resveratrol from red wine was performed. After culturing Bovine Aortic Endothelial cells (BAOECs) in resveratrol to ensure there was no adverse effect on normal cell growth and morphology, it was concluded that there was no effect due to resveratrol addition. An established way to model inflammation in BAOECs is by using Tumor Necrosis Factor-a (TNF-a), which induces a large accumulation of actin stress fibers. Our data suggest that resveratrol pretreatment reduces the amount of actin stress fiber accumulation, caused by TNF-a, thus exhibiting anti-inflammatory properties. A large amount of inflammation in the cardiovascular system is caused by a wound to the endothelial layer. A wound healing assay was conducted to determine the wound healing properties of resveratrol. Resveratrol was shown to dramatically aid in the wound healing process, compared to an untreated control. Furthermore, the immune response of the body to implantable devices was investigated using a THP-1 cell adhesion assay to polyurethane, a common biomaterial used in medicine. When a foreign material is introduced into the body, an immune response is stimulated, and monocyte-derived macrophages stick to the biomaterial, hindering its function. THP-1 cells are a good in vitro model of the monocyte-derived macrophages found in the immune system. THP-1 cell attachment to the polyurethane was significantly reduced in the presence of resveratrol. These data indicate that resveratrol possesses promising anti-inflammatory qualities that may prove to be useful in the prevention of cardiovascular disease, improving wound healing, and decreasing biomaterial rejection.

19-5 GREEN, PA*; CAVES, EM; ZIPPLE, MN; PETERS, S; JOHNSEN, S; NOWICKI, S; Duke University; *patrick.a.green@duke.edu*

Categorical Perception of a Carotenoid-based Assessment Signal

Animals use signals to assess quality, motivation, and other factors in contexts ranging from mate choice to aggression. Current models of signal evolution often assume that continuous variation in signal form is perceived in an equally continuous fashion by receivers; that is, any incremental change in the signal is perceived and equally influences subsequent decision-making. This assumption has rarely been tested, however, despite growing evidence showing that stimuli across modalities may be perceived in a categorical fashion. Carotenoid-based color signals are used in assessment of quality across diverse vertebrate taxa, yet few studies have asked how receivers perceive variation in these signals. We tested how female zebra finches (*Taeniopygia guttata*) perceive the continuum of carotenoid-based colors used in mate assessment. We identified eight colors along a range of orange-red coloration that approximate variation in male beak color, a signal used in mate choice, and that are approximately equidistant in a well-established color space based on avian color vision. After females had been trained to find food under bicolor discs, we then varied the colors comprising the two sides of the discs to determine the extent to which females perceived these colors as same or different. Female responses met both criteria of categorical perception: they (1) labeled colors along the continuum as falling into two distinct categories and (2) showed heightened discrimination of color pairs that crossed the category boundary as compared to equally-spaced pairs from within a category. Similar tests with grey scale stimuli showed that variation in brightness alone cannot account for these results. We discuss how categorical perception of assessment signals may inform models of signal evolution.

72-3 GREEN, TL*; WILBOURN, JL; O'BRIEN, HD; GIGNAC, PM; Oklahoma State University Center for Health Sciences, Tulsa, Oklahoma State University, Stillwater; *todd.green@okstate.edu*

Allometry of Common Ostrich (Struthio camelus) Ophthalmic Retia

Arterial thermoregulatory mechanisms (e.g., carotid retia in artiodactyls and felids) have been recognized as drivers of selective brain cooling, which is important for some endotherms that live in predominately hot climates. Among birds, thermal physiology and osmoregulation (e.g., water balance, renal function) have been studied in the largest extant bird, the common ostrich, a giant flightless species native to African deserts. Adults have been shown to utilize ophthalmic retia—arterial structures convergently similar to mammalian carotid retia—to aid brain and eye cooling. How this feature forms and grows during ontogeny, however, is not well understood. Rete development is of interest because ostriches grow rapidly, attaining most of their body mass in the first 1.5 years of life. Thermal and osmoregulatory needs may be in flux during this period due to the individual or combined effects of body-mass, metabolic, and arterial surface-area scaling. To elucidate ophthalmic rete ontogeny, we employed vascular injection and µCT scanning on a developmental series of ostriches to visualize and digitally measure retial, endocranial, and eye volumes using Avizo 9. Retial volumes appear to scale with negative allometry, such that young ostriches hatch with relatively well-developed retia that change little during the accelerated growth of their early ontogeny. We compare this finding with rete ontogenies in other endotherms capable of arterial cooling to more broadly address the configuration of such structures in the context of thermal and osmoregulatory issues faced by large-bodied vertebrates due to climate change.

110-5 GREENBERG, DA*; PALEN, WJ; Simon Fraser University; *dgreenbe@sfu.ca*

The role of hydration state and temperature on performance and climate susceptibility in amphibians

Forecasting species' responses to impending climatic change remains one of the most preeminent challenges for conservation science. Characterizing species' thermal performance curves has allowed us to mechanistically predict the effect of future warming on species' persistence. However, considerable changes to hydrologic regimes are also expected to occur in tandem with warming. Water stress, or the hydration state of an organism, is also known to be a limiting factor for many species, but our understanding of how performance changes with hydration state is still limited. Evidence also suggests that hydration state may potentially interact with body temperature to dictate performance, which could substantially alter estimates of species' vulnerability to future environmental change. Here, we assess the role of hydration state and temperature acting concurrently to dictate performance across six phylogenetically diverse amphibian species. We empirically tested: 1) the relative impacts of temperature and hydration on species' performance, 2) whether hydration state changes the shape of thermal performance curves, and 3) how combining both environmental axes changes estimates of species' climate risk. We show that hydration state has a strong negative effect on organismal performance, that it interacts with temperature for several species, and that integrating both hydration and temperature have the potential to affect estimates of species' climate risk. As most hydrologic regimes are forecast to change with climate change, our results suggest that an integrative physiological approach combining both hydration and temperature as environmental drivers of fitness will improve estimates of extinction risk under future climate change scenarios.

S10-6 GREENLEE, KJ*; BOWSHER, JH; RINEHART, JP; YOCUM, GD; GREENLEE, kendra; North Dakota State Univ., Fargo, USDA-ARS, Fargo, USDA-ARS, Fargo; *kendra.greenlee@ndsu.edu*

Beneficial effects of fluctuating thermal regimes: Increasing insect survival of low temperature stress

Insects exposed to low temperature stress may experience chill injury or death. Using fluctuating temperatures, in which insects receive a daily pulse of heat instead of constant low temperature stress has long been known to increase survival of insects in many life stages. The alfalfa leafcutting bee, *Megachile rotundata*, is a solitary, cavity-nesting bee that overwinters as a prepupa. Its survival of low temperature stress during overwintering is improved by a daily, one-hour pulse of heat. In addition, bees that have begun metamorphosis and are no longer in the protective state of diapause can be interrupted with low temperature stress to delay development. These interrupted bees also have improved survival when the low temperature stress is accompanied by a daily pulse of heat. Compared to constant low temperature stress, pupae that receive a daily warm pulse exhibit reversal of sub-lethal defects in adult wing morphology and flight performance. Bees exposed to fluctuating temperatures during pupal interruption also have better synchronization of adult emergence and increased reproduction compared to bees exposed to constant low temperature stress. Interestingly, these benefits exist even when the fluctuating temperatures are not ecologically relevant. The critical parameters of the fluctuating thermal regime that provide the beneficial effect (e.g., time spent above or below a thermal threshold, maximum or minimum temperature) are unclear. Understanding which parameters contribute to improved survival and fitness of these bees can help improve storage for commercially reared species and will help us to make better predictive models for how bee populations may respond to changing climates.

S6-3 GREENWAY, R.*; HAVIRD, J.C.; KELLEY, J.L.; TOBLER, M.; Kansas State University, University of Texas at Austin, Washington State University; *greenrs@ksu.edu*

The role of mitonuclear incompatibilities during ecological speciation in extremophile poeciliid fishes

Hybrid breakdown due to mitonuclear incompatibilities (incompatibilities between genes encoded by the mitochondrial [*mt*] and nuclear [*nuc*] genomes) is hypothesized to serve as a major contributor to speciation. Oxidative phosphorylation (OXPHOS), an essential biological pathway consisting of mitonuclear protein complexes, is a candidate for mitonuclear incompatibilities as hybridization between lineages can lead to the breakup of co-adapted OXPHOS proteins. Hydrogen sulfide (H_2S) rich habitats provide an ideal setting for testing hypotheses about mitonuclear incompatibility. H_2S is extremely toxic to most organisms because it inhibits OXPHOS, resulting in direct selection on OXPHOS. Despite extreme toxicity, tolerance to environmental H_2S is known from evolutionarily independent lineages of fish in the family Poeciliidae that have colonized H_2S-rich freshwater springs. Strong selection on OXPHOS genes should lead to the evolution of tightly co-adapted mitonuclear gene complexes in sulfidic lineages, increasing the likelihood of mitonuclear incompatibilities upon hybridization with non-sulfidic lineages. Using sequence data from sulfidic and closely related non-sulfidic lineages, we found evidence for positive selection on *mt* OXPHOS genes in sulfidic lineages, as well as on corresponding *nuc* OXPHOS genes in a subset of lineages. Protein structure modeling revealed amino acid substitutions occur at contact residues between *mt* and *nuc* encoded proteins in some lineages. Structural models of OXPHOS complexes for these lineages were used to quantify the effect of these substitutions on the thermodynamic stability of "hybrids" created by recombining OXPHOS subunits from sulfidic and non-sulfidic lineages *in silico*.

114-4 GREENWAY, G*; HAMEL, J; MILLER, CW; Univ. of Florida, Elon University; *egreenway@ufl.edu*

A Tangled Web: Why do Some Individuals Mate with the Wrong Species?

Reproductive interference, or reproductive interactions between heterospecific individuals, is commonly reported across taxa, but its drivers are still far from clear. One potentially powerful approach to uncover its causes is to examine an individual's heterospecific interactions in relation to it's conspecific mating behavior, within the broader context of the species' mating system. Here we use a social network approach to compare inter- and intraspecific mating dynamics in the squash bug *Anasa tristis* and its close relative *A. andresii*. Using replicated semi-natural enclosures, we surveyed the mating behavior of individually marked *A. tristis* bugs (10 males and 10 females per trial) at hourly intervals over a 10 day period using a robotic camera system. We then repeated this, replacing 5 *A. tristis* males and females per enclosure with *A. andresii* counterparts. Mating networks in intraspecific trials were highly saturated. Bugs mated with almost all available partners, inducing potentially high levels of post-copulatory sperm competition with little evidence of pre-copulatory selection. Despite high promiscuity, male mating effort was unevenly distributed across females; males typically had strong mating associations with just one or two females and weaker associations with all other partners. Similar patterns were observed in interspecific trials: around 20% of individuals engaged in heterospecific matings, but the majority of mating activity took place between conspecifics. Females from interspecific trials had comparable hatching success with those from conspecific trials. Consequently, relatively high levels of reproductive interference may emerge under semi-natural conditions as a byproduct of limited intraspecific pre-copulatory choice paired with limited fitness penalties.

S10-8 GREIVES, TJ*; GRAHAM, JL; BAUER, CM; North Dakota State University, Centre d'Ecologie Fonctionnelle et Evolutive, Adelphi University; *timothy.greives@ndsu.edu*

Daily rhythms in hormones and behavior, seasonal timing and reproductive success

Nearly all organisms display daily changes in physiology and behavior. Yet, substantial variation among individual daily rhythms exist; some individuals naturally begin their daily activity early (e.g. morning larks) while some begin their daily activity later (e.g. night owls). The mechanisms giving rise to individual variation and the relationships between behavioral rhythms and other important biological processes, such as seasonal and daily timing of breeding behaviors, are still not fully understood. Reproductive steroid hormones are excellent candidates for mediating timing of reproductive-related behaviors as these hormones are known to influence daily locomotor rhythms in captivity, and they display daily plasma rhythms. Little is known, however, about whether these daily hormone peaks (which generally occur at night) are repeatable, and whether variation in daily peak levels are related with variation in the basic organization of the hypothalamic-pituitary-gonadal axis. Here, we describe research from our group demonstrating peak baseline levels of testosterone during the nighttime, high repeatability of these levels, and strong relationships between nighttime levels and peak-induced levels following a ‘challenge' with gonadotropin-releasing hormone. Further, we will describe correlative studies in female songbirds that seek to link daily variations in behavioral and hormone rhythms with observed variation in seasonal clutch initiation.

S10-1 GREIVES, T; BOWDEN, RM*; North Dakota St U, Illinois St U; *rmbowde@ilstu.edu*

The world is not flat: accounting for the dynamic nature of the environment as we move beyond static experimental manipulations

The world that animals live in is constantly changing. Depending upon where they live, they may need to respond to daily changes in variables such as temperature or tidal cycles, or they may primarily respond to longer term, seasonal changes. For many animals, these changes in their environment result in concomitant changes in their physiological and behavioral state. And while physiological responses to environmental variability is widely acknowledged, much of the research that has advanced our understanding of the regulation of key traits are often conducted in ways that try to minimize variation. Whether conducted in the laboratory or the field, these studies have provided critical information about the mechanistic relationships that influence physiology and behavior that, in turn, influence variation in individual fitness, despite providing limited information on the direct effects of environmental variation. It is clear that we now need research approaches that explore how natural variation in the wild, or how experimentally mimicking nature under more controlled settings, affects physiological mechanisms and responses to this variation. Understanding why and how animals cope with environmental changes is key to recognizing the sources and subsequent responses that give rise to the variation that selection can act upon, particularly as environments change with a changing climate. The goal of this symposium is to highlight important insights that are gained when studies take into account these, often dramatic, changes across daily and seasonal time scales, and to stimulate future research that is needed to better understand how animals may cope with a changing climate.

P3-92 GRIESBACK, K*; HARTMAN, R; TOBE, S; SCOTT, K; LANDBERG, T; Arcadia University; *kgriesback@arcadia.edu*

Heavy Metal Contaminants in Snapping Turtle Soup from the Philadelphia Area

Snapping turtle soup is a historic dish that remains a menu item in restaurants and taverns in the Philadelphia area. Unfortunately, heavy metals such as iron, lead, mercury and zinc are common in the aquatic environments where these turtles live, and these metals accumulate in turtle tissues through the food web. Though heavy metals negatively affect their reproduction and recruitment, snapping turtles can survive in polluted environments. We examined snapping turtle meat as a food source due to its high potential to transfer acquired heavy metals to the humans that consume it. Samples of snapper soup were acquired from restaurants throughout the lower Delaware River watershed in Pennsylvania (n=40). Meat, fish, and poultry typically contain a level of zinc around 29 ppm, while in vegetables it can be up to 2 ppm. Initial chemical analysis shows that several turtle meat samples contain a level of zinc greater than these values, and greater than the recommended daily intake value (8 mg per day or 0.11 mg/kg for females and 11 mg per day or 0.14 mg/kg for males). The zinc levels in the samples are not high enough to cause toxicity independently, but combined with other zinc-containing foods consumed in the daily diet, turtle meat can contribute to greater overall zinc levels in the body. High zinc content can cause harmful physiological effects. While our other heavy metal analyses are ongoing, snappers may contain nearly all toxic metals- for which there are no safe levels of consumption. This, combined with ecological data showing that continued harvests of turtle populations for consumption is unsustainable, suggests that snapper soup may be detrimental to both humans and turtles.

P2-267 GRIFFIN, C*; BOTELHO, J; HANSON, M; FABBRI, M; BHULLAR, A; Virginia Tech, Yale University; *ctgriff@vt.edu*

The Avian Pelvis Possesses Ancestral Dinosaurian Character StatesEearly in Development

The avian body plan is unique among all other vertebrate groups and was assembled in stages over millions of years. The avian pelvis in particular is conspicuously different from the ancestral reptilian condition, providing adaptations suited to the biomechanical demands of flight (e.g. anteroposteriorly expanded ilium and sacrum, backward-facing pubis, shifts in hindlimb muscle sizes and uses), and so the evolution of this region is key to the origin of Aves. However, whereas the evolution of this region is recorded by extinct forms, how development has influenced the formation of the avian body plan is poorly constrained, leaving a major knowledge gap that precludes an integrated understanding of avian evolution. The avian pelvis could be constructed in one of two ways: 1) the derived avian condition could be present at the outset of morphogenesis, as in the avian beak; 2) the beginning of morphogenesis could resemble the ancestral condition, with derived character states accumulating during prenatal development. Here, we use a new method of imaging embryonic tissues in three dimensions—immunostaining cleared embryos and stacking the resulting confocal microscope images in computed tomography software—to demonstrate that the avian pelvis possesses ancestral archosaurian and dinosaurian conditions (e.g., forward-facing pubis, short ilium, anteriorly directed obturator muscle, shorter abdominals), progressively gaining the derived avian character states during development. Therefore, unlike some portions of the avian body, the beginning of pelvic morphogenesis resembles the ancestral condition of many key characters. In addition to the fossil record, the means of transitioning from typically ‘dinosaurian' to avian locomotion can be studied through development.

110-1 GRIFFITHS, JS*; JOHNSON, KM; KELLY, MW; Louisiana State University; *jgrif61@lsu.edu*

Evolutionary Change in the Oyster, Crassostrea virginica, Following a Low Salinity Event

The eastern oyster, *Crassostrea virginica*, is known for its tolerance of a wide range of salinities, but evidence suggests that some populations may be adapted to their local salinity regime. Distance from the Mississippi River is correlated with increased salinities and oysters are expected to have a decreased tolerance to low salinity as distance from the Mississippi River increases. Larval survival is strongly influenced by the salinity conditions of the parental stock, suggesting that larvae from their ‘home' or ‘parental' salinity regime have higher survival than in a ‘foreign' environment with a different salinity. Oysters have high levels of gene flow which could impede local adaptation, but strong selective gradients may cause differential survival of native and foreign oyster recruits, leading to population structure and adaptation to local salinity regimes. To test for evidence of local adaptation by differential larval survival we imposed a low salinity (7 ppt) selection event on oyster larvae from Louisiana (low salinity environment) and Texas (high salinity environment) populations. A subsample of larvae was collected before and after a 12-hour low-salinity exposure for genetic analyses. "Live" oysters were collected from the top 900mL of the jar and "dead" oysters were collected from the bottom 100mL of the jar. We observed 99% mortality in larvae from the high salinity Texas population and only 70% mortality in larvae from the low salinity Louisiana population, suggesting population-specific survival rates. Using exome capture, we sequenced 150 salinity-associated genes and observed allele frequency shifts in survivors before and after low salinity exposure. These genes are potential candidates under low salinity selection that maintain population structure in *C. virginica* in the Gulf of Mexico.

3-2 GRIM, J/M*; PAWLAN, J; BOWEN, V; BROSNAN, E/B; MCMAHON, T/A; University of Tampa; *jgrim@ut.edu*

Amphibian hosts experience decreased metabolic rates and diminished stress responses during the time course of chytridiomycosis

The proximate cause of wide-spread amphibian death following infection with chytrid fungus (*Batrachochytrium dendrobatidis*- Bd) has been reported as a loss of organismal osmotic regulation, leading to cardiac arrest. More recently, earlier changes in gene expression have been detected, indicating that organismal function might be compromised more quickly after infection than previously expected. No one has examined, to our knowledge, how or if metabolic rate changes during the time course of Bd infection. We infected adult Cuban tree frogs (*Osteopilus septentrionalis*) with Bd and measured whole animal metabolic rate during the time course of a six-week infection. Exposure to Bd resulted in a rapid loss of metabolic rate following just eight days of infection, with continued loss of metabolic rate as the infection progressed up to six weeks. Additionally, we observed possible evidence of changes to host stress response in these metabolic data. Our interpretation of these data was supported by behavioral experiments in which we assessed the stress response of individuals during the time course of infection. In general, uninfected individuals were more sensitive to stimulus and moved further than uninfected individuals after six weeks of exposure. The early loss of metabolic rate and associated decrease in stress response indicates that amphibian hosts may be impacted earlier in the time course of infection than expected. These physiological changes may leave infected amphibians at elevated risk of negative outcomes as both diminished predators and increasingly susceptible prey.

110-8 GRIMES, CJ*; SCHULZE, A; Texas A&M University at Galveston; *cg1478@tamu.edu*

How the sluggish cope with chronic hypoxia: the pointed story of the bearded fireworm, Hermodice carunculata (Annelida: Amphinomidae)

The bearded fireworm, *Hermodice carunculata* (Annelida: Amphinomidae), is a widespread mobile corallivore throughout the Atlantic Ocean. Due to its extensive geographic distribution, abundance, and survival under low oxygen conditions, it may serve as a model organism for hypoxia studies, which are increasingly important with the projected escalation of hypoxia zones in the future. Molecular, morphological, and physiological responses of *H. carunculata* to hypoxic conditions were investigated to estimate the dissolved oxygen (DO) level at which they are affected. Five bearded fireworms were exposed to one of three levels of DO in 40-liter tanks for seven days: 2.5 (± 0.25) mg/l, 4.5 (± 0.25) mg/1, and 7 (± 0.25) mg/1 (normal DO). No reference genome exists for the species, so a combined reference transcriptome was assembled from all sequences and utilized to align the RNAseq data from individuals for differential gene expression analysis. Additionally, we monitored oxygen uptake rates throughout the experiments and conducted morphometric analyses of branchial morphology. Pairwise comparisons of transcriptomes revealed up-regulation of key hypoxia and stress response genes and down-regulation of metabolic pathway genes in the worms under hypoxia. Differences in gene regulation were noted between the two experimental groups, indicating the DO levels chosen were distinct enough to invoke differing responses. The oxygen uptake rates and filament number were higher in the hypoxic treatments, indicating 7 days is enough time to induce morphological and physiological responses to hypoxia. The results allow us to infer the threshold DO level for hypoxic response in this abundant and environmentally tolerant coral predator, and to predict downstream responses.

117-4 GRIPSHOVER, ND*; JAYNE, BC; Univ. of Cincinnati ; *ngripshover@gmail.com*

Testing How Gape and Prey Size Affect Feeding Performance in a Crayfish-eating Snake

Snakes are a model system for studying how anatomy affects feeding performance because their maximal gape constrains the size of prey that can be swallowed whole. However, maximal gape of snakes has rarely been measured directly. Despite having diverse diets, snakes rarely consume hard-bodied prey, yet crustacean specialists have evolved convergently in natricine and homalopsid snakes, which eat crayfish and crabs or shrimp, respectively. For the natricine *Regina septemvittata*, which eats only freshly molted crayfish, we tested how predator anatomy and prey size affected feeding performance and behavior by quantifying: 1) scaling relationships of maximal gape (N=25), 2) relative size of prey (prey area/ gape area) consumed in the field (N=145), and 3) effects of relative prey size on prey handling times and behavior during laboratory trials (N=107). For snakes with snout-vent lengths of 17-59 cm, maximal gape areas were 2.8-28.4 cm^2 and had a scaling exponent (1.643; 95% CL =±0.373) not quite significantly less than geometric similarity (2). Of the field-caught snakes, 88% and 39% ate prey with relative sizes >50% and > 90%, respectively. During laboratory trials relative prey size predicted 45% of the variation in prey handling time. In 85% of trials the snakes held the prey and reduced its mobility before swallowing. For the same relative prey area, the predicted handling times of *R. septemvittata* are longer and shorter than those of the homalopsids that eat soft-shelled and hard-shelled crabs, respectively, but nearly identical to a homalopsid that eats snapping shrimp with a shape more similar to crayfish. These results nicely illustrate how predator anatomy, gape and behavior, and the size, shape and hardness of prey all have important consequences for feeding performance.

P2-132 GROSSKOPF, SM*; MCALISTER, JS; College of the Holy Cross; *smgros20@g.holycross.edu*

Investigating Potential Macroalgal Diets for Larvae of the Sea Urchin Arbacia punctulata

Sea urchin adults have relatively diverse diets of benthic macroalgae, whereas larvae are thought to feed primarily on unicellular phytoplankton. Although recent research demonstrates that kelp detritus can serve as a high-quality food source, it is not entirely understood what role various other macroalgae may play in the diets of larvae. Our goal in this study was to determine if other benthic seaweeds found in adult urchin habitats could provide for similar larval growth, as does kelp. In a pilot study, we determined that larvae of the sea urchin, *Arbacia punctulata*, would consume lab-made detritus of the common intertidal seaweeds *Ulva intestinalis* and *U. lactuca*, *Laminaria agardhii* (kelp), *Fucus* sp., and *Chondrus crispus*, but preferred kelp and *Fucus*. Next, we reared *A. punctulata* larvae under four replicated food treatments: high and low concentrations of the unicellular microalga *Isochrysis galbana* (a standard proxy for phytoplankton), and separate seaweed slurries made from kelp and *Fucus*. We found that *A. punctulata* larvae can grow while consuming kelp and *Fucus* detritus. However, the larvae reared under the *Fucus* and kelp diets did not grow as extensively within 10 days as larvae provided with a high, satiation diet of *Isochrysis*. Larvae consuming *Isochrysis* grew to the 8-arm stage within 10 days whereas the majority of the larvae fed *Fucus* and kelp were still at the 4-arm stage. We are continuing data analysis of this experiment as well as a second experiment that replicated the conditions of the first and will present comprehensive results from both at the SICB Annual Meeting. This project provides an avenue for further research into the diets of sea urchin larvae. Future related studies might examine the effects on larval growth of mixed macro- and microalgae food treatments.

76-5 GRUNBAUM, D*; EMLET, R; Univ. Washington, OIMB; *random@uw.edu*

The Function of Minimalist Morphologies: Swimming Performance of Blastulae, Gastrulae and Other Spheroidal Organism Architectures

Late stage marine larvae and many other plankton develop complex morphologies with features such as arms or other extensions, skeletons, and cilia or muscles that play important roles in orientation, speed and other elements of swimming performance. Equally interesting, and perhaps more basal in evolutionary history, are blastulae, gastrulae and other organisms with minimalist, spheroidal morphologies that swim, are subject to performance requirements, but lack elaborations traditionally associated with swimming. How do these "simple" organisms swim, and how are their morphologies constrained by the need to do so? Cell divisions that produce blastulae or gastrulae with uneven distributions of tissue have preferred orientations that are stable in still water and provide righting moments in turbulence. Theory predicts that if these stages have locomotory structures that are radially distributed around the axis determined by the offset centers of mass and buoyancy, they will swim in a direction parallel to this axis until the intensity of water motion overcomes their shape-dependent orientation abilities. We explored this prediction and inference by surveying the initial swimming stages of marine invertebrate taxa and with computational simulations which model shape, centers of mass and buoyancy and various arrangements of locomotory cilia.

30-8 GUERRA CANEDO, VI*; BYRNE, M; HART, MW; Simon Fraser University, The University of Sydney; *vguerracanedo@gmail.com*

Codon-model analyses of selection associated with the evolution of different modes of reproduction in sister species of sea stars

We compared patterns of episodic diversifying selection among genes assembled from denovo transcriptomes of *Cryptasterina pentagona* and *C. hystera*, which recently speciated (6,000 years ago) and have evolved different mating systems (gonochoric or hermaphroditic), modes of fertilization (outcrossing or selfing), and dispersal (planktonic larvae or internal brooding). We used three complementary models of codon evolution (MEME, BUSTED, aBSREL) to find sites or lineages under positive selection in each gene, and gene ontology methods to characterize the functions of positively-selected genes. The results from this study show that the genes with the largest numbers of sites under selection were linked to immunity (e.g., *NLRC5-like*) and extracellular-matrix-bound calcium signaling (integrin *Fibronectin-like*). Other positively-selected genes encoded intracellular calcium signaling of the acrosome reaction (e.g., voltage-dependent calcium channel subunit alpha-2/delta-1) and sperm-egg binding (e.g., egg coat bindin receptor *OBi1*). Prior work detected little evidence of selection on sperm bindin, and we found that the egg coat bindin receptor *EBR1* was partially truncated in *C. hystera* (but not *C. pentagona*). These results suggest that the resolution of sexual conflict (via the evolution of selfing hermaphroditism in *C. hystera*) has led to relaxed selection on some gamete recognition genes, and may have led to reduced specificity of fertilization. The results help to highlight possible targets of selection acting on these species, and warrant carrying out a direct test of gamete compatibility within and between them.

102-4 GUINDRE-PARKER, S*; MCADAM, A; BOUTIN, S; HUMPHRIES, M; LANE, J; COLTMAN, D; DANTZER, B; University of Guelph, University of Alberta, McGill University, University of Saskatchewan, University of Alberta, University of Michigan; *slg2154@columbia.edu*

Do glucocorticoid hormones respond to selection in free-living North American red squirrels?

Glucocorticoid hormones are dynamic and flexible, and allow animals to cope with perturbations in their environment by coordinating behavioural and physiological responses. As a result, glucocorticoids (CORT) often play a role in shaping fitness and are thought to promote adaptive responses to environmental change. Despite the importance of CORT as a mechanism of phenotypic plasticity, little is understood about how this coping mechanism arises as most studies on the topic have been performed at an ecological scale rather than an evolutionary one. Though breeding experiments in captive animals have demonstrated that CORT can respond to artificial selection, little is understood about if and how endocrine systems evolve in free-living systems. We use a longitudinal hormone and fitness dataset collected in North American red squirrels (*Tamiasciurus hudsonicus*) to uncover whether selection acts on CORT in natural systems. In this study population, CORT has important fitness implications because this hormone mediates an adaptive maternal effect. First, we use tools from quantitative genetics to (i) calculate the heritability of this trait, and (ii) partition variance in CORT among different possible components (i.e. maternal effect, environmental effect, cohort effect, etc). Second, we use results of an experimental evolution manipulation to determine whether CORT responds to selection in natural systems. This study contributes to evolutionary endocrinology by improving our understanding of how hormonal coping mechanisms arise in free-living populations.

P1-159 GUINDRE-PARKER, S*; RUBENSTEIN, DR; University of Guelph, Columbia University; *slg2154@columbia.edu*

The physiological costs and fitness benefits of group living trade-off in an unpredictable environment

The fitness consequences of group living have been difficult to study in cooperatively breeding species, where it remains challenging to disentangle the benefits of living in a social group from those of alloparental care behavior. Both group living and alloparental care may increase the ability of organisms to cope with harsh environments, though the former remains poorly studied. We use a long-term dataset collected in cooperatively breeding superb starlings (*Lamprotornis superbus*) to determine the fitness consequences of group living, as social groups are significantly larger than, and uncorrelated to, the number of alloparents present in each group. We examined (i) whether social group size increased adult survival, (ii) whether group size served to buffer against harsh environmental conditions, and (iii) whether survival benefits of social group size were mediated by physiological traits (i.e. glucocorticoid hormones, oxidative stress, and immune function). Survival models showed that group size was positively correlated to adult survival, though differently between the sexes: female survival increased with group size similarly across all environmental conditions, whereas male survival increased with group size in periods of average or above average pre-breeding rainfall (though there was no benefit to living in the largest group under harsh conditions for males). We also found that physiological state did vary according to social group size, though individuals in the smallest and largest social groups paid the greatest physiological cost. Our results suggest that while individuals in the largest social groups gain the largest fitness benefits, they simultaneously experience the greatest physiological costs. Harsh environmental conditions may increase social conflict, particularly in males, leading to reduced benefits of group living under harsh dry years.

P1-142 GUINNESS, AA*; O'TOUSA, JO; University of Notre Dame Eck Institute for Global Health; *aguinnes@nd.edu*
A genetic toolkit for comparative analysis of light-triggered behaviors in mosquito species
An animal's interaction with sensory cues in their surrounding environment is key to their ultimate success in development, feeding, and reproduction. Modification of the genetic machinery regulating how these cues integrate into the behavior and the ecology of medically significant animals is a promising control strategy. Light is one of the most frequent and important cues that animals interact with daily. Previous work in our lab has described retinal specializations in mosquitoes compared to the well-studied Drosophila melanogaster. This includes an expansion of the rhodopsin gene family and light-triggered rhodopsin movement enhances the mosquito's visual capabilities in dim light. *Ae. aegypti* and *Ae. albopictus* are vectors of medically-important arboviruses including Dengue and Zika, and the *Culex pipiens* complex is the primary vector for West Nile Virus. Thus these three species all pose a significant public health challenge. However, these species have markedly different ecologies and therefore likely differ in their strategies for host-finding and other behaviors. Comparing photoreceptive physiological traits among these mosquito species will allow us to dissect the role of vision in these behaviors. CRISPR-Cas9 gene editing technology has simplified the creation of genetic modifications in non-model organisms. Here we describe our efforts to apply these methods to create visually-impaired mosquitoes of each species. We intend to carry out behavioral assays on these strains coupled to Bayesian models to characterize key factors of visual behavior.

P1-174 GUMM, JM*; IMHOFF, VE; FELLER, KD; US Fish and Wildlife Service; Stephen F. Austin State University, Stephen F. Austin State University, University of Cambridge; University of Minnesota; *jennygumm@gmail.com*
A novel sexually dimorphic, light induced color change in a mantis shrimp, Coronis scolependra
While Stomatopod crustaceans are well known for their incredible visual systems, aspects of their coloration have received less attention. Previous studies of stomatopods examine the evolutionary patterns and behavioral functions of coloration, and document observations in color polymorphisms. Changes in body coloration in stomatopods and other crustaceans have been linked to molting. In other taxa, changes in body coloration may be influenced by many factors including, but not limited to, circadian rhythms, developmental stage, seasonality, temperature, background color, social interactions, and stress. Herein we quantify a novel color change in a Nannosquillid stomatopod that is both sex limited and light induced. *Coronis scolependra* (family Nannosquillidae) is a spearer-type mantis shrimp that constructs sand burrows in shallow, tropical waters. It is one of the few known sexually dichromic Stomatopods; with males of the species a light sandy color and females a dark brown. However, at night females reduce their melanic coloration and resemble males. This change is reversible, and females return to their dark brown color when they are exposed to light. We document the extent and temporal pattern of the light induced color change. Further, we provide preliminary evidence that the cycling of female color change may be under circadian control. Sexual dimorphism is often associated with sexual selection, although may also reflect differences in life history or physiology between the sexes. This study establishes a framework for future studies to determine what drives this female limited color change.

26-5 GUNDERSON, AR*; RIDDELL, EA; ROSENBLUM, EB; Tulane University, UC Berkeley; *argunderson3@gmail.com*
Balancing the need to stay warm and stay safe: thermal consequences of color evolution in White Sands lizards
Animal coloration can influence multiple aspects of performance. Therefore, color evolution is likely to be mediated by a balance of selection on multiple functions. The White Sands Desert is home to three lizard species that have independently evolved blanched coloration relative to the ancestral color of adjacent dark soil populations. Blanched coloration in the White Sands is thought to be an adaptation to avoid predation via increased background matching. However, it is also likely to have thermal consequences for White Sands lizards by changing the amount of solar radiation they absorb. Are these thermal effects beneficial, detrimental, or neutral? We applied a biophysical modeling approach to estimate the effects of coloration on operative thermal environments and temperature-dependent physiological and behavioral performance. Relative to ancestral coloration, we found that blanched coloration reduces the annual number of hours with overheating risk by 20%. However, relative to ancestral coloration, blanched coloration also reduces the annual number of hours that activity can be achieved within the preferred temperature range, though by only 3%. Our results indicate that the blanched coloration of White Sands lizards has thermal consequences, some of which are positive (reducing overheating risk) and some of which are negative (reducing activity). Therefore, multiple ecological forces may have contributed to color evolution in this system.

P2-82 GUO, Y.; CLARK, E.C.*; RENN, S.C.P.; Reed College, Portland State University; *mifguo@reed.edu*
Hunger in the Operant Conditioned Cichlid A. burtoni. Quantified in Velocity by an Arduino based Robotic System
Female *Astatotilapia burtoni*, a species of mouthbrooding cichlid fish, 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 suppress feeding behavior, 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 to automate the quantification of hunger or feeding motivation in *A. burtoni* using the speed to approach a food-conditioned stimulus. They are conditioned to approach the feeder sensor through the gate sensors upon stimulus of a signaling light, they then subsequently trigger the feeder sensor to release food when they are sufficiently close. Once the fishes are conditioned and brooding, they are tested with a program that doesn't dispense food. This eliminates the consummatory act of feeding in the process of quantifying brood care motivation and will allow us to investigate the underlying neural and physiological mechanisms. Arduino systems are routinely used in robotics education at a high school level and lower, so these experiments offer the opportunity for outreach and collaboration.

P2-242 GURGIS, GP*; DAZA, JD; BRENNAN, IG; HUTCHINSON, M; BAUER, AM; OLORI, JC; SUNY Oswego, NY, Sam Houston State University, TX, Australian National University, Canberra, South Australian Museum, Adelaide, Villanova University, PA; *jennifer.olori@oswego.edu*

3D Geometric Morphometric Analysis of Pygopodid Gecko Skull Morphology and Relationship to Habitat

Pygopodids are an enigmatic group of limb-reduced geckos that live in a variety of habitats within Australia and New Guinea. Despite low taxonomic diversity, pygopodids exhibit a wide array of skull morphologies, sometimes within a single genus. For example, *Aprasia* from Western Australia differ from Eastern and Central species by elongating the parabasisphenoid rostrum and reducing the epipterygoid. To investigate differences in skull shape across pygopodids and assess potential ecological associations, CT scans of 12 specimens from six genera were used for 3D geometric morphometrics. We recorded 29 landmarks in Landmark Editor, and used Geomorph to perform Generalized Procrustes Alignment, Principal Components Analysis, and MANOVA to test for associations with habitat (fossorial, ground, low-shrub, high-shrub). Habitat correlated significantly with shape differences. PC1 (skull depth, orbit shape) explained 46% of the variation whereas PC2 (snout elongation, occipital shape) explained 15%. Fossorial taxa (all *Aprasia* we included) were widely separated from other habitat types along PC1, and the highly elongate *Lialis* was isolated in shape space. Within *Aprasia*, taxa separated along PC2 into Western and Central/Eastern clusters, and MANOVA of *Aprasia* species confirmed geography to be a significant factor. We suggest that the two *Aprasia* morphotypes, and a second genus *Ophidiocephalus*, took different evolutionary paths to achieve head shapes conducive to fossoriality. However, less is known about the locomotor and feeding patterns of pygopodid species, which also may influence morphology and could drive the separation within habitat types.

38-3 GUSMãO, LC*; GRAJALES, A; RODRíGUEZ, E; American Museum of Natural History, Universidade de los Andes; *Lgusmao@amnh.org*

Sea Anemones Through X-rays: Utility Of Micro-computed Tomography (Micro-CT) for the taxonomy and systematics of the group

Morphological studies of sea anemones (Cnidaria: Actiniaria) combine complementary techniques: gross dissections provide information on internal features in three dimensions and with low resolution whereas histology provides resolution at the cellular level in two dimensions. The appeal of micro-computed tomography (micro-CT) is its potential to improve characterization of morphological features by combining qualities of both methods with comparable cost and avoiding some of their shortcomings (e.g. slowness, small volumes, artifacts). Given the paucity of morphological characters used in the taxonomy of Actiniaria and the difficulties of establishing primary homologies, micro-CT has the potential to advance our understating of evolutionary patterns and offer insights into details of traditionally used characters. We show that micro-CT efficiently delineated morphological features in sea anemones despite the need for chemical staining due to sea anemone's low-density tissue. Satisfactory staining of all tissue types resulted in high-contrast images consistent between scanned specimens with fine details of external and internal anatomy readily observed in 2D micro-CT images and 3D volumetric renderings. Because phylogenetic signal can be evaluated only when the presence and variability of a morphological character has been reliably determined, we discuss the advantages and limitations of incorporating micro-CT data in taxonomic and evolutionary studies in the group. Furthermore, we explore the potential of using this technology in the study of comparative anatomy of polyps across the Class Anthozoa which has been hindered by challenges in implementing traditional histological methodologies.

P1-67 GUTHERZ, SB*; O'CONNOR, PM; Ohio University; *sgutherz0819@gmail.com*

Postcranial Skeletal Pneumaticity in Cuculidae

Birds possess unique modifications of the tetrapod *Bauplan*, including pneumatization of the postcranial skeleton that results from invasion of bone by respiratory epithelium. The degree of pneumaticity in living birds varies greatly among taxa. Previous research has characterized the degree of pneumaticity in selected Avian groups and proposed evolutionary hypotheses, frequently related to body size and/or ecological drivers, in which this variability is framed. This study focuses on Cuculidae, a heretofore unsampled clade that occupies an early branching position in Neognathae and exhibits a broad distribution of body sizes, geographic ranges and types of habitat occupied. Sixteen species were sampled, capturing much of the aforementioned diversity and representing all major cuclid subclades. Skeletal specimens from museum collections were examined for osteological correlates of pneumaticity, with anatomical regions for each specimen scored based on the presence/absence of pneumatic features. This survey reveals both phylogenetic and ecological signals. In both Crotophaginae and Neomorphinae, the basic pneumaticity condition includes aeration of the sternum, humerus, femur, pelvic girdle, dorsal ribs and entire vertebral column except C1. In Cuculinae, Couinae and Centropodinae, the same patterns exist with the exception of the femur. The femur has the greatest variability across Cuculidae, with slightly more than half the specimens sampled exhibiting a pneumatic femur. Other variable regions include bones of the pectoral girdle and the tibiotarsus. In addition to a phylogenetic signal, there appears to be a relationship between relative pneumaticity and both body size and preferred habitat (e.g. terrestrial vs. arboreal).

P1-90 GUTIERREZ-PINTO, N*; LONDOñO, GA; CHAPPELL, MA; STORZ, JF; University of Nebraska-Lincoln, Universidad ICESI, University of California Riverside; *nguti@huskers.unl.edu*

The effect of elevation on the aerobic scope of Andean birds

The aerobic scope (VO_{2max}/BMR) defines an animal's endurance during energy-demanding behaviors necessary for survival. Additionally, the maximal rate of aerobic activity in vertebrates is determined by an individual's ability to obtain, transport, and utilize oxygen (O_2), which is in limited supply at high-elevations (i.e. hypoxia). Hypoxia is especially acute for small, active endotherms like passerine birds that cannot use metabolic suppression as a means of reducing O_2 requirements. Consequently, it can be expected that there are compensatory physiological mechanisms in place to maintain VO_{2max} and BMR at high elevations. Nevertheless, efforts to evaluate the causes of variation in maximal energy use across bird species have not been explicitly developed in the context of elevation. In this study, we compare five pairs of closely-related bird species with contrasting elevational ranges in the Colombian Andes to test for associations between native elevation range and aerobic scope. Preliminary results suggest that high- and low- altitude species have similar VO_{2max}, BMR, and aerobic scopes, which should reflect changes in the underlying architecture and mechanisms (e.g. size of relevant organs or Hemoglobin-O_2 affinity) that allow high-elevation individuals to maintain the same rate of basal and maximal O_2 utilization in spite of low O_2 availability.

98-1 HAASE, CG*; FULLER, NW; HAYMAN, DTS; HRANAC, CR; OLSON, SH; PLOWRIGHT, RK; MCGUIRE, LP; Montana State University, Texas Tech University, Massey University, Massey University, Wildlife Conservation Society; *cghaase@gmail.com*

Bats Are Not Squirrels: Revisiting the Cost of Cooling in Hibernating Mammals

Many species use stored energy to hibernate through periods of resource limitation. Hibernation, a physiological state characterized by depressed metabolism and body temperature, is critical to winter survival and reproduction, and therefore has been extensively quantified and modeled. Hibernation consists of alternating phases of extended periods of torpor (low body temperature, low metabolic rate) and energetically costly periodic arousals to normal body temperature. Arousals consist of warming, euthermia, and cooling phases. Warming and euthermic costs are regularly included in energetic models, but although cooling to torpid body temperatures is an important phase of the torpor-arousal cycle, it is often overlooked. When included, cooling cost is assumed to be 67% of warming cost, as measured in a single ground squirrel species, regardless of body size or ambient environment. We derived a model of cooling cost from first principles and validated the model with empirical energetic measurements. We compared the assumed 67% proportional cooling cost with our model-predicted cooling cost for 53 hibernating mammals, including 17 bat species. Our results indicate that using 67% of warming cost only adequately represents cooling cost in ground squirrels. In smaller species, this proportion overestimates cooling cost. Our model allows for the generalization of energetic costs for multiple species using species-specific physiological and morphometric parameters. Our model also allows for predictions over variable environmental conditions, which is imperative in understanding the bioenergetic effects of white-nose syndrome.

P1-264.5 HAFFNER, C*; FOSTER, P; ANDERSON, SJ; COWLES, DL; Walla Walla University; *carston.haffner@wallawalla.edu*

Are Pentidotea resecata Isopods Biting the Hand that Feeds Them? A Study on the Spatial Correlation of Isopod Bite Marks and Wasting Disease on Eelgrass, Zostera marina

As a vital component of many coastal marine ecosystems worldwide, seagrass beds serve as a habitat, food source, and nursery for many species and provide a buffer against the erosive nature of waves and currents. In temperate North America and Europe the main seagrass is eelgrass, *Zostera marina*. In the past a protist pathogen, *Labyrinthula zosterae*, has at times devastated eelgrass beds by causing eelgrass wasting disease. Although wasting disease has not recently spread epidemically in the eelgrass beds in Washington State, *L. zosterae* is commonly present at low concentrations. Understanding the mechanism by which it spreads is important for understanding the potential for future outbreaks. The large green eelgrass isopod *Pentidotea resecata* lives within and feeds upon eelgrass blades. It is an accomplished swimmer and frequently moves from blade to blade, and so could potentially serve as a vector for spreading the disease. In this study we examined the correlation in the laboratory between isopod bite marks and the location of new wasting disease lesions on eelgrass blades collected from Padilla Bay, WA. New *L. zosterae* lesions were significantly more likely to occur on blades that had bite marks than on those which had not been fed on. Additionally, on blades with both bite marks and lesions, the lesions appeared significantly closer to the bite marks than would be expected from a random distribution. These results imply that the feeding and movement of *P. resecata* between eelgrass blades may enhance the spread of the disease.

P2-238 HAGER, ER*; HOEKSTRA, HE; Harvard University; *ehager@fas.harvard.edu*

Functional Significance of Differences in Tail Morphology in Deer Mice

Adaptation to novel habitat often involves changes in both morphology and behavior, which can interact to influence performance. Deer mice (*Peromyscus maniculatus*) in forested habitats have repeatedly evolved longer tails and feet than those from neighboring non-forested habitat. Previous work showed that the presence of the tail is likely critical for balance in deer mice. However, the functional significance of natural variation in tail length has not been tested, and covariance among morphological traits in wild populations makes it challenging to quantify the functional significance of each aspect of morphology independently. In addition, behavioral differences between forest and non-forest populations may interact with morphological variation to produce performance differences among populations. Here we show that forest mice from eastern and western North America have not only evolved convergent tail and foot morphologies, including increases in both the length and number of caudal vertebrae, but also exhibit convergent behavioral traits in a standard climbing assay. Even in laboratory-born, naïve mice, we observe consistent behavioral differences in both climbing preference and climbing performance between forest and non-forest populations, suggesting these differences are genetic. We then use a large, laboratory intercross between forest and prairie ecomorphs to generate mice with novel trait combinations. By quantifying climbing performance in this large recombinant population, we measure the relative importance of the various aspects of the forest morphology for climbing performance, and thus directly test the long-standing hypothesis that long tails have evolved in forest deer mice as an adaptation for arboreal locomotion.

P3-7 HAGEY, TJ*; PHILLIPS, J; GERING, E; Mississippi University for Women, University of Idaho, Michigan State University; *thagey@muw.edu*

Microhabitat Texture of Invasive Hawai'ian Arborael Lizards

The adhesive toes of geckos and some other lizards have the remarkable capability to generate strong adhesion and friction on rough and smooth surfaces, allowing these animals to move through their environments unlike many other animals. The adhesive toe pads of lizards are extremely diverse, nearly as diverse as the habitats these species live in. Pad bearing lizards can be found living in rocky, arboreal, and terrestrial microhabitats in arid, temperate, and topical environments. How the adhesive toe pads of these species may be adapted to their particular microhabitats is an open question. The extensive work on pad bearing Caribbean and South American anole lizards have highlighted some adaptive patterns correlating toe pad morphology with habitat use, as well as how microhabitat adaptation can facilitate habitat partitioning and ecomorphological diversification. We investigated habitat partitioning in relation to perch texture. Perch texture remains a greatly understudied area with expected mechanical interactions with toe pad performance. Conducting fieldwork in Hawai'i, we quantified the texture of perches used by three invasive arboreal diurnal lizards species to investigate if perch texture is acting as an axis of habitat partitioning.

P2-87 HAHN, TP*; CUSSEN, VA; DINGLE, H; ROBART, AR; WATTS, HE; CORNELIUS, JM; Univ. of California, Davis, Washington State Univ., Eastern Michigan Univ.; *tphahn@ucdavis.edu*

The omnivore's opportunity: Importance of alternate foods for movement, molt and reproduction in diet specialist, nomadic songbirds

Diet specialists are particularly susceptible to fluctuations in food supply. A high degree of mobility allows some to use a Rich Patch Exploiter strategy, moving from one pulse of high food availability to another. Although this may allow them to spend most of their time in locations with abundant food, it may also require them to move long distances through regions where their specialized diet is not available. Two tactics for coping with this challenge are: (1) prepare for the move by laying down fuel reserves to be used during the movement, and (2) exploit other food sources besides their typical specialized diet while moving. Crossbills (*Loxia* spp.), and to a lesser extent pine siskins (*Spinus pinus*), are diet specialists, depending heavily on seeds of coniferous trees. As Rich Patch Exploiters, they annually move long distances through regions of few or no seeds in search of abundant conifer seeds. Both prepare for annual (spring/early summer) nomadic migration by depositing fat reserves to fuel long distance flight (tactic 1). However, since distance moved and destination vary from year to year, it seems likely that they may also need to employ tactic 2. Here we demonstrate that they rely heavily on insect foods (e.g., aphids, lepidoptera larvae) that are abundant on coniferous and other trees during the spring/early summer movement period. We also discuss importance of these insects to other components of their annual cycles (reproduction, plumage molt). Periodic reliance on alternative dietary components may be widely important in Rich Patch Exploiting diet specialists such as these finches.

120-1 HALE, MD*; MCCOY, JA; DOHENY, BM; GALLIGAN, TM; GUILLETTE, LJ; PARROTT, BB; University of Georgia, College of Charleston, University of Minnesota, Virginia Tech, Medical University of South Carolina; *matthew.hale@uga.edu*

Embryonic Origins of Altered Ovarian Transcriptional Networks in an Environmental Model of Endocrine Disruption, the American Alligator

The American alligator population inhabiting a contaminated Florida lake has served as a valuable environmental model for understanding the adverse effects of endocrine disrupting contaminants (EDCs) on reproductive development and heath. Using targeted approaches, previous studies have revealed persistent changes to ovarian transcription and suppressed responsiveness to gonadotropins in exposed individuals. In an effort to identify novel genetic pathways impacted by EDCs, we used an unbiased RNA-seq approach to describe transcriptional networks in the alligator ovary and the role of the embryonic environment in modulating responsiveness to FSH. Alligator eggs collected from the contaminated lake, Lake Apopka (AP), and a reference site, Lake Woodruff (WO), were hatched and raised for five months under laboratory conditions, then challenged with FSH or a vehicle control. We identify a suite of canonical FSH-responsive genes in both populations, including steroidogenic enzymes CYP11A and CYP17A, inhibins, and cyclin-related factors. Furthermore, we identify a strong influence of site in both non-challenged and challenged transcription; while populations share a suite of core responsive genes, each exhibits site-unique transcriptional responses. Additionally, approximately 12,000 genes in the non-challenged ovary differ by site, indicating a large degree of plasticity in ovarian function across populations. Collectively, these results suggest that developmental EDC exposure might play a substantial role in eliciting persistent transcriptional shifts in the ovary.

P1-257 HALE, E*; ZOHDY, S; SCHWARTZ, T; Auburn University, Auburn; *ech0025@auburn.edu*

Detection and Quantification of West Nile, Rift Valley Fever, and Dengue Fever Viruses from Dried Blood Spots to Identify Zoonotic Potential

Wildlife, non-human primates (NHPs) in particular, can serve as reservoirs for arboviruses such as Dengue (DF), West Nile (WNV), and Rift Valley (RVF) fever viruses, which can all be found in human populations in Madagascar. To better understand the zoonotic potential of Malagasy wildlife species to act as reservoirs of these viruses, methods for rapid, minimally invasive sample collection and preservation are necessary. With this study we aim to (1) develop a qPCR protocol for detection and quantification of DF, WNV, and RVF viruses, (2) validate the use of dried blood spots on TropBio cards as a method for detecting RNA viruses, (3) to determine the prevalence of these viruses in wild NHP species (lemurs of Madagascar). To validate the protocol, we apply the viral RNA genomes, or house mouse (*Mus musculus*) blood spiked with inactivated viral particles to TropBio cards. RNA was isolated from the cards and the target viral RNA was detected by qPCR. Mouse lemur blood samples were collected from intact forest and deforested regions of Madagascar. Ongoing work will test mouse lemur blood spots for these viruses using this protocol.

38-1 HALL, KC*; HUNDT, PJ; SWENSON, JD; SUMMERS, AP; CROW, KD; University of Washington, University of Minnesota, University of Massachusetts Amherst , San Francisco State University ; *kchall8@uw.edu*

The Evolution of Underwater Flight in Manta Rays and Their Relatives (Myliobatidae)

Batoids (skates and rays) are a diverse clade of flat cartilaginous fishes that occur primarily in benthic marine habitats. They typically use their flexible pectoral fins for feeding and propulsion via undulatory swimming. However, two clades of rays have adopted a pelagic or bentho-pelagic lifestyle and utilize oscillatory swimming—the Myliobatidae and Gymnuridae. Oscillatory swimming is associated with changes in pectoral fin morphology, including lateral elongation, a redistribution of pectoral fin rays, and the evolution of modified anterior pectoral fin domains called cephalic lobes- anteriorly extended appendages used for feeding in the Myliobatidae. Variation in the number of fin rays in batoid pectoral fins has not been characterized in a comparative or phylogenetic context. To better understand how the batoid body plan was modified in association with a shift in feeding and swimming modes, we quantified fin rays that articulate with the three primary cartilages of pectoral fins and cephalic lobes in myliobatids and their relatives. Additionally, we analysed how morphology of the anterior primary cartilage varies in relation to dual-functionality. While most undulatory swimmers exhibit symmetry, we found a posterior shift in the distribution of fin rays arose twice independently. The shape and segmentation patterns of the anterior primary cartilage varies among batoid genera and is linked to feeding and swimming mode. Further, we described a derived skeletal feature in anterior pectoral fins of the Myliobatidae. Overall, this research has implications for morphological evolution associated with invasion of the pelagic environment, and the biomechanics of underwater flight.

84-4 HALL, JM*; WARNER, DA; Auburn University; *jmh0131@auburn.edu*

Constantly Fluctuating in an Inconsistent Way: Comparing the Effects of Sinusoidal and Naturally Fluctuating Incubation Temperatures on Embryo Development

Temperature is a commonly studied environmental factor influencing embryo development in oviparous ectotherms. Though most studies use constant temperature incubation conditions, researchers are aware of the effects of fluctuating temperatures on development. Daily-repeating sinusoidal fluctuations are now commonly used in studies of developmental plasticity; however, thermal fluctuations in natural nests are highly variable from day to day. Thus, using repeated, uniform fluctuations (e.g. sine waves) may still provide an incomplete picture of how embryos develop in the wild and generate inaccurate predictions of how species will respond to future thermal conditions (e.g. climate change). We used eggs from the brown anole lizard (*Anolis sagrei*) to test the effects of realistic nest temperature fluctuations vs constant temperatures and sinusoidal fluctuations in the lab. We used temperature data from nests to create 4 incubation treatments: a constant mean temperature, a daily-repeating sine fluctuation, a daily-repeating asymmetrical fluctuation (i.e. mean, hourly nest temperatures), and a treatment that allowed each day's thermal fluctuation to differ from all other days as in real nests. These 4 treatments were created for both early-season (March-April, relatively cool) and late-season (June-July, relatively warm) nest temperatures (2 by 4 factorial design; season x incubation treatment). We report results for developmental rates, physiology (VO2 and heart rate), embryo survival, as well as morphology, performance, growth, and survival of hatchlings. By comparing the effects of several commonly used experimental thermal regimes with those of natural fluctuations, our study assesses the importance of using ecologically relevant incubation conditions when studying developmental plasticity in the laboratory.

S2-8 HALL, RJ; University of Georgia, Athens; *rjhall@uga.edu*

Modeling the Effects of Anthropogenic Stressors on Immune Defense and Infection Dynamics in Heterogeneous Host Populations

Variation in host competence can lead some individuals to contribute disproportionately to pathogen transmission. Exposure to anthropogenic stressors that impair immune performance could increase the proportion of "supershedding" individuals and thus alter the size and duration of epidemics. In order to predict how living in stressful environments influences outbreak severity requires models that couple stress-mediated immune function in individuals to population-level transmission dynamics. Here I use a within-host model of immune cell-pathogen interactions to investigate how stressors that restrict the energy allocated to immune defense determine pathogen colonization and host infectious period. At the population level I assume that individuals vary in their acquisition and allocation of resources in stressful environments, and use the within-host model to generate a distribution of infectious periods. Finally I couple within and between host processes by simulating epidemics on this heterogeneous host population. This approach represents an initial attempt to incorporate natural and stress-induced variation into infection models that bridge immunological and epidemiological scales.

P3-115 HALL, A.M.*; ZARDUS, J.D.; BOWDEN, J.B.; MCFEE, W.E.; NAPOLITANO, M.N.; College of Charleston, Charleston SC, The Citadel, Charleston SC, University of Florida Veterinary School, Gainesville FL, NOAA, Charleston SC, NOAA/NIST, Charleston, SC; *hallam@g.cofc.edu*

A Lipidomic Approach to identifying Immune Response in Cetacean Skin to the Attachment of the Tassel Barnacle Xenobalanus globicipitis

The pseudo-stalked tassel barnacle, *Xenobalanus globicipitis*, is an obligate commensal of cetaceans predominantly attaching to the fins and flippers of dolphins and other small whales in tropical and subtropical waters around the world. The life cycle and natural history of this species is little known as it occurs only sporadically across cetacean hosts making it difficult to study. This research explores the potential immune response of cetacean skin and plasma that may be induced by settlement of this barnacle. Plasma and non-invasive skin stripping discs collected from live dolphins during a health assessment in Sarasota, FL were extracted using traditional and novel lipid extraction techniques, respectively. The extracted samples were processed using an untargeted LC-MS/MS approach in positive, negative, and full scan modes and a list of lipids present was compiled for each sample using LipidMatch software. These lipid profiles will be assembled and compared between groups of dolphins with and without *X. globicipitis* attached during health screenings. lipid profiles will be analyzed using a PCA and significant lipids associated with an immune response will be identified. Any significant differences in lipid profiles of animals with and without barnacles attached would be indicative of a potential new health risk for dolphin populations and could open the door for further cetacean immunology studies.

P2-6 HALL, MR*; BERG, O; MüLLER, UK; California State University Fresno; *umuller@csufresno.edu*

Bladderwort as a model organism to study predator-prey interactions in an ambush predator

Bladderworts are a carnivorous plant genus (*Utricularia*) containing several aquatic species; the latter form hundreds of millimeter-sized underwater traps to capture zooplankton prey. The large number of very small traps makes these plants ideal model organisms to study predator-prey interactions in a batch mode (mesocosm). In a laboratory microcosm we pit dozens to hundreds of prey against dozens to hundreds of predators in a small volume (mason jars) for a brief period (hours to days). We monitor the progress and outcome in terms of prey size and type, as well as trap age, size, capture rate, and capture efficiency. To this end, we have developed assays involving machine vision, fluorescence imaging, and sound recording. We can now address such questions as ‘how energetically expensive are active traps?' and ‘how do prey size or predator size affect capture rate and capture success?'. An individual trap becomes active at the growing end of the plant, then captures and digests dozens of prey items before dying at the senescing end of the plant. We found that young traps have high rates of unsuccessful or spontaneous fires and that the majority of prey items are caught by mature, large traps. Using the volume of water inspired as a measure of the energy expended by traps, we found that small traps spend the most energy despite catching the fewest prey. This finding is contrary to the expectation that energy expenditure should correspond to capture success. The volume of water pumped is furthermore a proxy for the oxidative stress of respiration, which is believed to be a central factor in bladderworts' extremely small genome and high rate of molecular evolution.

P3-25 HALL, J; ABEYESINGHE, S; DALEY, MA*; Royal Veterinary College; *mdaley@rvc.ac.uk*

Interactions between personality expression and locomotor dynamics in helmeted guinea fowl (Numida meleagris)

Helmeted guinea fowl (*Numida meleagris*) have served as a useful animal model for bipedal locomotion, with well-studied features of gait dynamics, musculoskeletal function, energetics, and muscle-tendon dynamics. Yet, wider aspects of behavior have been sparsely studied in guinea fowl. Literature on other vertebrates suggests that individuals within species vary in behavior along a bold/shy personality axis, and these differences are stable across contexts. Bold individuals readily explore novel environments and exhibit higher levels of locomotor activity and lower frequency of observable stress behaviors. We have measured bold/shy personality expression and locomotor dynamics in a flock of guinea fowl in a longitudinal study. Exploratory behavior and activity levels in various environments were used to quantify bold/shy personality expression. We find evidence that, like other species, guinea fowl do exhibit stable variation among individuals consistent with bold/shy personality. In separate experiments, we also measured locomotor dynamics of the same flock of birds while executing turning maneuvers on terrains of different friction. We found that running speed during turns varied significantly among individuals, and the random effect coefficients for individuals from a mixed-model ANOVA showed a positive correlation with independently measured bold/shy personality scores ($r = 0.61$). We also see evidence that ‘bold' individuals exhibit a greater learning effect across repeated trials than ‘shy' individuals. These preliminary findings suggest interesting interactions between personality and locomotor dynamics, which warrants further consideration for how biomechanics studies can be designed to adequately capture behavioral variation among individuals within a species.

58-4 HALL, BE*; BIGMAN, JS; BEDORE, CN; Georgia Southern University, Simon Fraser University; *bh06426@georgiasouthern.edu*

Scaling and ecological relationships in the visual ecology of sharks

Visual adaptations such as eye size (i.e. eye diameter), acuity (the ability to discern detail), sensitivity (the amount of light needed for image formation), and pupil shape can be used to infer the relative importance of vision to an organism. Eyes and the visual processing system are metabolically costly to maintain, suggesting that large relative eye size (as it relates to body length) may have a significant ecological or evolutionary role, such as mate selection, predator avoidance, and foraging strategy. Elasmobranchs comprise a morphologically diverse group that has successfully filled a wide range of marine and freshwater niches. Several species occupy different predatory niches across their lifetime as their energetic and ecological demands shift, yielding a wide range of visual habitats. As eye size changes with body length ontogenetically, they represent an ideal group for examining scaling relationships, such as eye growth rate (i.e. slope) and eye size at a given body length (i.e. intercept) within the context of visual habitats. In this study, we quantified the relationship of eye size and body length in 6 species of sharks and compared this scaling across species that differ in ecological lifestyle (i.e. activity level, habitat, and maximum size). Eyes of all species scaled hypoallometrically with body size, however larger and more active species (e.g. the white shark *Carcharodon carcharias*) had larger relative eye sizes than smaller, less active species (e.g. the Atlantic sharpnose shark *Rhizoprionodon terraenovae*). Larger eyes for active predators may provide either greater sensitivity or greater visual acuity which would enable these species to carry out visually-guided behaviors across a wide range of visual habitats.

45-4 HALL, AS; Thermo Fisher Scientific, Houston, TX; *alex.hall@thermofisher.com*

Segmentation and Meshing for Biomechanical Finite Element Analysis

Originally designed for engineers, finite element analysis (FEA) is a digital technique for understanding how materials respond to applied physical forces. In biology, FEA can be used to understand how all or part of an organism responds to the forces of flight, combat, locomotion, etc. across taxa, between individuals, or through life. In biological data from X-ray computed tomography or laser scanning, assigning parts of an organism to a material typically requires subjective segmentation. Additionally, FEA takes volumetric meshes as input and the quality of this mesh can have a dramatic effect on the interpretation of the FE model. Both steps, then, require objective and accurate approaches for meaningful FE simulation. Using Amira with the XImagePAQ and XWind extensions allows users to automate segmentation workflows and easily generate accurate tetrahedral meshes for FEA. Our software now uses a new Delauney refinement for generating tetrahedral meshes which improves upon our legacy advancing front method. The previous method could produce nonconforming meshes with poor aspect ratios and slivers and might not converge. The new method prioritizes the creation of tetrahedrons with 'good' aspect ratios that are not too-small or too-large and is entirely automated. The result is a conformal unstructured tetrahedral mesh that can be directly exported to commercial FEA solvers such as Abaqus, ANSYS, and COMSOL Multiphysics. This presentation will include a discussion of our improvements to meshing with related biomechanical modeling case studies.

S11-8 HALLGRIMSSON, Benedikt*; KATZ, David C.; APONTE, Jose D.; GONZALEZ, Paula N.; LARSON, Jacinda R.; DEVINE, Jay P.; MARCUCIO, Ralph S.; University of Calgary, CONICET, Argentina; *bhallgri@ucalgary.ca*

Integration and the Developmental-Genetics of Allometry

Allometry refers to variation in organismal shape that correlates with size. It is a form of integration that is special because variation in size is ubiquitous within and between species. Allometry is so commonly observed that it is routinely removed from analyses or invoked as an explanation for evolutionary change. In this case, familiarity is confounded with understanding because rarely do we know the mechanisms by which shape correlates with size or understand their significance. As with other forms of integration, allometric variation is generated by variation in developmental processes that affect multiple traits, resulting in patterns of covariation. Given this perspective, we can dissect the genetic and developmental determinants of allometric variation. Our work on the developmental and genetic basis for allometric variation in craniofacial shape in mice and humans has revealed that allometric variation is determined by multiple processes that are related to growth and timing which may have different effects on trait associations. Different measures of size are often associated with different patterns of allometric variation. Further, many mutations result in covarying effects on size and shape that differ markedly from expected allometric patterns. Nutritional stress produces timing-dependent effects of allometric variation, and growth deficient mice treated with growth hormone recover shape in a manner that depends on the timing of treatment. Finally, the genetic determinants of allometric variation are very complex and involve mainly genes with little obvious relationship to the central determinants of growth. These results question the view of allometry as a coherent phenomenon distinct from morphological integration more generally.

P1-230 HALSEY, MK*; STUHLER, JD; BRADLEY, RD; STEVENS, RD; RAY, DA; Texas Tech University; *michaela.halsey@ttu.edu*
Opportunistic sampling, model-based clustering and least-cost path analysis aid in identification of connectivity corridors in the Texas Rolling Plains
At a time when biodiversity is declining at an alarming rate, it is encouraging that the technology and data afforded to conservation biologists continues to increase. Assessment of fine scale shifts in species distributions and the processes of dispersal and gene flow are made possible by the availability of multilocus molecular markers. Herein, genetic variation was assessed in two species of kangaroo rats (*Dipodomys ordii* and *D. elator*) to identify such patterns. Of the two kangaroo rat species we examined, *D. elator* is endemic to Texas, and is a soil specialist whose population is likely declining due to land use change. Demographic differences influenced by population size are expected to be reflected in the genome of each species. We compared the genetic variability of 59 individuals from eight counties in Texas using a variant of restriction-site associated DNA marker sequencing (RAD-Seq). Individuals were assigned to population clusters using STRUCTURE. Landscape complexity was characterized using a series of models to identify potential barriers to gene flow. Our results suggest that despite differences in ecology, behavior and evolutionary history between these two species, their gene flow response to the complex landscape of the Texas Rolling Plains is similar. Furthermore, we propose that we can evaluate barriers to connectivity in a threatened kangaroo rat species using a more widespread surrogate. Such an approach will provide biologists the unique opportunity to test hypotheses that otherwise may be unfeasible with small, threatened populations and can enable the development of conservation strategies and investigative frameworks that better manage and conserve imperiled species, such as the Texas kangaroo rat.

P2-271 HAMM, AR*; RILEY, AG; MULLIN, MM; ECKERLE, BM; LEHTINEN, RM; CARLSON, BM; The College of Wooster, Ohio; *ahamm20@wooster.edu*
To Delete or Not to Delete: Examining the Role of Mc1r Deletions in Squirrel Melanism
Polymorphism has long interested evolutionary biologists as important variation from the standpoint of selection as well as a possible route to speciation. Color polymorphism, in particular, is widespread in many taxa and is important in conspecific interactions, predator avoidance, thermoregulation, and other important functions. Different color variants (such as melanism) may present both costs and benefits to individuals displaying variant phenotypes. While melanistic individuals remain a rarity in some populations, other populations harbor melanism at a relatively high frequency in the absence of an obvious selective benefit. In order to better understand the evolutionary significance of these phenotypes, especially where they persist at high levels, it is important to identify the genetic basis of this variability. Previous work in the gray squirrel, *Sciurus carolinensis*, identified a 24 base-pair deletion in the *melanocortin I receptor* gene (*Mc1r*) that showed a strong association with melanism in introduced populations in the United Kingdom, as well as a small number of individuals from Massachusetts, Virginia, and British Columbia. In this study, we sampled *S. carolinensis* in Wooster, OH, where melanistic individuals account for ~70% of the local population. Our results confirm that the same *Mc1r* deletion observed elsewhere is indeed present in the Wooster population. However, our results also suggest that the relationship between the presence of this deletion and the development of melanism may not be as simple as previously thought. Further investigation is necessary to fully understand the genetic basis of this phenotypic variation.

P1-56 HAMMOND, L; CERRA, K*; CURET, O; PORTER, M; MEREDITH, T; Florida Atlantic University; *tmeredi1@fau.edu*
Follow that smell: Fluid dynamics through the shark olfactory organ
Elasmobranchs (sharks, skates, and rays) are known for their acute olfactory sense. Olfactory system morphology is diverse and varies interspecifically, but the links between morphology and function are unclear. We hypothesize that variations in morphology impact the fluid flow through the olfactory organ and in turn have consequences for olfactory sensitivity. The shark olfactory system consists of an incurrent channel, an excurrent channel, and the organ itself, which is comprised of two rows of lamellae, which are overlain with olfactory epithelium. The shape of the organ and number of lamellae vary dramatically among species. Our goal was to use bioinspired models to examine the impacts of varying organ shape and lamellar number on flow through the olfactory organ. We based bioinspired models on varying meristics for the organ (length, width, and depth) and for the lamellae (number, width, and interlamellar distances). Particle Image Velocimetry was used to quantify the effects of meristic variation on flow patterns and rates through the model. We found that vortices are generated in each interlamellar space. In addition, we observed that flow distribution between lamella changes along the length of the organ. These flow characteristics likely have implications for odorant biding. However, these flow structures still need to be corroborated at lower Reynolds number. These data suggest that the variations in olfactory morphology may be important for distributing fluid through the system to the sensory epithelia and information processing.

P1-35 HANDY , SH*; ARNETTE, JP; CEJA , M; POFF , MA; OWERKOWICZ, T; California State University, San Bernardino; *towerkow@csusb.edu*
Heat Exchange Through the Skin of the American Alligator: Do Osteoderms Play a Role?
Osteoderms in crocodilians are known to function in mechanical protection, locomotor support, and acid-base regulation. With a rich vascular supply, osteoderms are also thought to play an active role in crocodilian thermoregulation, allowing the animal to absorb or dissipate heat faster than has non-ossified dermis. We tested this hypothesis by monitoring superficial and deep temperatures of juveniles of the American alligator (body mass 0.3-30 kg) during warming and cooling between 15 and 30°C. We recorded skin surface temperatures with an infrared camera, and core temperature with a cloacal thermocouple. We controlled for cutaneous perfusion by running the experiments first on live animals and then on their carcasses. We found, unsurprisingly, that animal size has a significant negative effect on rate of heat exchange. Further, warming (to 30°C) occurred significantly faster in live animals than carcasses, but differences in cooling (to 15°C) were not appreciable. Scales with osteoderms (in the cervical and dorsal regions) showed small (<2°C) differences in temperature profile from neighbouring scales without dermal bone. These temperature differences were most pronounced at the start of each experiment, and disappeared with each experiment duration. Notably, these temperature differences were not consistent between anatomic regions within an animal, or between animals (i.e., scales with osteoderms sometimes showed higher, sometimes lower surface temperature). Importantly, these temperature differences were similar in carcasses. This suggests that heat exchange through the crocodilian skin is dependent more on thermal characteristics of individual scales, and their anatomic location, than on vascular perfusion of underlying tissue, with or without osteoderms.

16-6 HANEY, W.A.*; STROTHER, J.A.; Oregon State University; *haneyw@oregonstate.edu*
Out of the dark and into the light: light preference behaviors in larval zebrafish.
The stress response of vertebrates can be initiated by many different environmental stimuli including extreme temperatures, noxious chemicals, mechanical disturbance, and pain. These sensory inputs are integrated within the central nervous system (CNS), which then drives responses in the peripheral nervous and endocrine systems. Catecholamines and cortisol are released into the blood, resulting in a cascade of physiological changes that includes shifts in heart rate, blood pressure, and plasma glucose levels. Although the physiological effects of stress have been well-studied, it is not well understood how the stress response reciprocally affects neural responses within the CNS. Zebrafish larvae are an ideal organism in which to examine this question, since they are very well-suited to most behavioral and neurobiological methods. Larval zebrafish exhibit a weak preference for well-lit areas, and previous studies have suggested that stress modulates this behavior by enhancing light preference. We conducted a broad survey of this behavior in order to identify the features of the visual stimulus that affect this behavior, the specific kinematic changes that produce the observed light preference, and the effects of specific stressors (temperature, electric shock, noxious chemicals) on responses. Our results suggest a simple model for how visually-induced changes in kinematic patterns produce the observed light preference, and how stress-mediated changes in these responses affect this preference.

5-5 HANSON, HE*; KILVITIS, HJ; SCHREY, AW; MADDOX, JD; MARTIN, LB; Univ. of South Florida, Georgia Southern Armstrong Campus, Field Museum of Natural History; *haleyhanson@mail.usf.edu*
Epigenetic Potential in Immune Genes of Introduced House Sparrows
Epigenetic potential, defined as the capacity for epigenetically-mediated phenotypic plasticity, may play an important role during range expansions. During range expansions, populations may encounter relatively novel challenges, including pathogens, while experiencing lower genetic diversity due to bottlenecks and/or founder effects. Phenotypic plasticity may allow individuals to rapidly cope with these challenges. Here, we asked whether one form of epigenetic potential (i.e. the abundance of CpG sites within gene promoters) varied among native and introduced populations of house sparrows (*Passer domesticus*) in three microbial surveillance genes: Toll-like Receptors 1B (TLR1B), 2A (TLR2A), and 4 (TLR4). Evidence suggests that increased expression of TLR2 and TLR4 may play a role in house sparrow range expansions, and that methylation at one CpG site within the putative promoter region of TLR4 was a predictor of TLR4 expression. We characterized i) total CpG sites, ii) total additions of CpG sites, and iii) losses of CpG sites in TLRs 1B, 2A, and 4. We hypothesized that introduced populations would have more total CpG sites via more additions and fewer losses of CpG sites (or overall higher epigenetic potential). We found that introduced populations had a higher total number of CpG sites in TLR2A and TLR4, but not in TLR1B. Additionally, the lower number of CpG sites was related to the lower genetic diversity of these introduced populations. Surprisingly, we found that low genetic diversity predicted a higher number of additions in CpG sites in TLR2A and fewer losses of CpG sites in TLR4. This suggests that selection is acting on CpG sites in introduced populations and that epigenetic potential may facilitate house sparrow range expansions.

67-4 HANSON, M*; BURNHAM, D; BRIGHT, J; CARNEY, R; BHULLAR, B-A S; Yale University, University of Kansas; *michael.hanson@yale.edu*
The First Three-Dimensional Reconstruction of the Skull and Musculature of a Cretaceous Toothed Bird, Hesperornis regalis
Cranial kinesis in birds is a remarkable anatomical specialization involving the development of novel joints resulting in a complex biomechanical system that allows the bill to move independently of the braincase. The early evolutionary history of the specialized musculoskeletal structures necessary for a fully kinetic skull, however, is poorly understood. Whereas nearly all Mesozoic bird skull fossils are crushed flat, fossil marine toothed bird *Hesperornis regalis*, from Late Cretaceous Kansas, is the closest fossil taxon to crown Aves with known from nearly complete, undistorted skull material, making it crucial for understanding the emergence of kinesis in birds. The three-dimensionally preserved skull material can be integrated with osteological correlates to musculature and mobile joints from living species to reconstruct the cranial kinetic system of *Hesperornis*. We µCT scanned and digitally prepared *Hesperornis* skull elements to construct a model for comparative and functional studies. We used contrast-stained µCT scans of palaeognathous and neognathous birds, and a crocodylian, to precisely identify osteological correlates to the cranial kinetic system and cranial musculature. With these comparative data, we developed a reconstruction cranial muscles in *Hesperornis*. The palate, rostrum, and some correlates to musculature compare favorably with palaeognaths, lacking mobile interpterygoid joints or a nasofrontal hinge, and kinesis relying on elastic deformation of the rostral bones. We also identify a suite of osteological correlates to jaw adductor muscles on the braincase resembling those in disparate clades of extant pursuit-diving birds, showing a mosaic of deeply plesiomorphic characters occurring in concert with remarkable convergence and specialization.

134-1 HANTAK, MM*; KUCHTA , SR; Ohio University ; *mh433113@ohio.edu*
Spatial Variation in Ecological Divergence in a Widespread Polymorphic Salamander
An open question in color polymorphic species is why morph frequencies are variable among populations. Little work has been done to examine geographic patterns in polymorphisms, with most studies focusing on a single population. The Eastern Red-backed Salamander, *Plethodon cinereus,* has a widespread distribution in the northeastern United States and southeastern Canada, and is color polymorphic throughout portions of its range. Two color morphs are common: a ‘striped' morph that has a red stripe overlaid on a black dorsum, and an ‘unstriped' morph that is completely black. Previous studies on single populations of *P. cinereus* have suggested that the two morphs differ in elements of their ecology, behavior, and physiology, yet a mechanistic understanding of the ecological differences between the morphs, and the evolutionary processes that maintain the polymorphism, remains unclear. In northern Ohio, many populations with varying morph frequencies of *P. cinereus* exist. Here, we established six sites that varied in morph frequency, including two populations that are monomorphic for unstriped (95-100% unstriped), two that are polymorphic, and two that are striped. At each site 100 porcelain tiles (1 ft2) were placed in a grid. These cover objects provided repeatable, standardized, high quality territories for the salamanders. We gathered ecological data from each site to determine if morphs were divergent in dietary composition and whether they assortatively mate by color. Our results demonstrate that while there was spatial and temporal variation in diet, morphs did not differ in dietary prey composition or volume. Conversely, we found that color morphs assortatively mated by color in two of three polymorphic populations. Overall, this study provides essential data for understanding variation in ecological interactions between the morphs over space and time.

P1-61 HARDY, AR*; HALE, ME; Univ. of Chicago; *arhardy7@uchicago.edu*
Mechanoreceptor distribution in fish pectoral fins: Clues for optimal sensor placement
The fins of fishes are innervated with sensory nerves and specialized endings capable of providing proprioceptive and tactile feedback. Across ray-finned fish studied, the sensory nerves extend distally within each ray following fin ray branching patterns. Nerve fibers exit the rays to innervate the inter-ray membrane, synapsing with mechanoreceptors. Mechanoreceptors respond to deformation of the fin and as the key link to the environment their location, number, and distribution may reflect adaptations to a particular habitat or fin function. To explore this further, we examined mechanoreceptor distributions in round goby (*Neogobius melanostomus*) pectoral fins, which frequently interact with the bottom substrate. Immunolabeling revealed a non-homogenous distribution of mechanoreceptors across the fin with fin rays located closest to the substrate exhibiting the highest concentrations. We found the highest density of endings within a ray in locations of fin ray branching. As these fin regions spread and deform during contact we suggest fin ray branching points may be particularly informative locations from which to sense contact and changes in fin ray position. These results lead to many questions regarding sensor placement, redundancy of the sensory system, and function of fin ray branching patterns. In an effort to tackle these questions, we compare our data in round goby to that of other species that vary in their frequency of substrate contact, pectoral fin function, and morphology and develop phylogenetically framed analyses in order to better elucidate the structure-function relationship of fin ray sensation.

86-3 HARMS, KS*; PAGE, LR; University of Victoria, BC, Canada; *ksharms@uvic.ca*
Surprise in a Small Package: Foregut Metamorphosis in an Ectoparasitic Snail (Pyramidellidae)
Members of the Pyramidellidae are tiny marine snails with highly unusual feeding habits relative to other heterobranch gastropods. They are described as ectoparasites because they feed on body fluids of much larger animals by extending an elongate proboscis, piercing the host's skin with a stylet, and creating suction with a muscular bulb. Foregut anatomy of pyramidellids is so complex and modified that homologous relationships to foregut components of other heterobranch gastropods are difficult to recognize. However, correctly identifying homologs is a necessary first step toward reconstructing evolutionary changes to the foregut developmental program of pyramidellids. Many pyramidellids begin life as a veliger larva that feeds on phytoplankton using ciliated velar lobes and a larval digestive tract like those of other gastropod veligers. Our goal was to compare foregut development through metamorphosis in the pyramidellid *Odostomia tenuisculpta* with that of other gastropods to understand how the derived state of the foregut is generated during development. By examining thick and ultra-thin sections of larval and metamorphic stages, we conclude that the so-named acrembolic proboscis of this pyramidellid is actually an eversible oral tube and the piercing stylet is a single, highly modified radular tooth, rather than a jaw derivative as previously suggested. Surprisingly, except for the salivary glands and ducts, much of the highly complex, multi-component foregut of the post-metamorphic stage is constructed during a 4-5 day period of explosive metamorphic morphogenesis. This stands in marked contrast to predatory neogastropods, in which most components of the post-metamorphic feeding system become extensively differentiated in the larval stage prior to settlement and metamorphosis.

P2-158 HARO, D*; BURKE, RL; PAULY, GB; LIWANAG, HEM; California Polytechnic State University, Hofstra University, Natural History Museum of Los Angeles; *daharo@calpoly.edu*
Cold tolerance plasticity and cold acclimation of non-native Italian wall lizard (Podarcis siculus) populations from New York and California
Thermal tolerance data are collected to increase our understanding of how closely an organism's physiology reflects adaptation to its environment. Unfortunately, because thermal tolerance can be highly plastic, sensitive to prior housing conditions, and sensitive to methods of measurement, comparisons between and within studies can be complicated. Though we know that thermal tolerance is plastic, to understand how it relates to adaptation to the thermal environment, it is important to study how plastic it can be. To do this, we measured cold tolerance of two non-native populations of *Podarcis siculus* once weekly during a cold acclimation treatment. Heat tolerance, thermal preference, evaporative water loss, and standard metabolic rate were also measured before and after the cold acclimation treatment. We found that the population of *P. siculus* from the more variable climate (Long Island, NY) was able to shift its cold tolerance relatively quickly, whereas the population from the milder climate (San Pedro, CA) did not shift its cold tolerance. NY lizards also decreased thermal preference while CA lizards did not. Temperature coefficients (Q_{10}) of water loss and metabolism were greater in CA lizards. Overall, results suggest that NY lizards are more adapted to a varying thermal climate compared to CA lizards. This underlying difference in plasticity, a potentially adaptive trait, would not have been detected if lizards had only been tested once prior to the cold acclimation treatment. These findings highlight the need to incorporate plasticity into theory and experiments investigating potentially adaptive traits.

P1-59 HARRIS, MD*; DEORA, T; ROTH, E; Univ. of Washington, Indiana Univ.; *monicah555@gmail.com*
Spatial Content of Visual Scenes Mediates Different Strategies for Gaze Fixation in Hawkmoths
As they navigate their environments, insects must parse the moving visual scene and respond to different features appropriately. In particular, they must distinguish between visual motion arising from their own movements relative to the environment (ego-motion) and those arising externally. Ego-motion creates optic flow across the entire visual field, called wide-field motion. In contrast, an external agent moving in the visual field (e.g. a wavering flower or an approaching predator) stimulates only a small patch that travels coherently across the retina, hence called small-field motion. To fixate a moving scene, the hawkmoth, *Manduca sexta*, can either reorient its entire body or change the angle of its head to redirect gaze. For pitch stabilization, moths respond predominately to wide-field motion, modulating both body posture and head orientation to follow expansive visual stimuli. Our recent experiments also show that for some visual scenes, moths exhibit head movements strongly correlated to the small-field visual motion, suggesting that head motion and body posture reorientation are separable strategies for visual fixation. To identify these parallel strategies, we investigate which aspects of the visual scene elicit head motion by changing the relative salience of the wide- and small-field stimuli. Moths are tethered at the center of a cylindrical visual arena and presented an image of a flower against mottled backgrounds of varying contrast and spatial frequency. The flower and background oscillate vertically at different temporal frequencies. A Fourier analysis reveals the extent to which the moth nods its head in response to each stimulus. Our data suggests that moths use the head-motion strategy to follow the small-field target provided the background has sufficiently low spatial frequency (blurry and lacking prominent edges).

P2-252 HARRISON, JS*; PORTER, ML; MCHENRY, MJ; ROBINSON, HE; PATEK, SN; Duke University, Univ. of Hawaii, Manoa, Univ. of California, Irvine, Humboldt State University; *jacob.harrison@duke.edu*

Scaling of elastic mechanisms: the tiny strikes of larval mantis shrimp

Mantis shrimp (Stomatopoda) strike prey using an elastic mechanism in their raptorial appendages. Across species, adult mantis shrimp use appendages that range up to 4 cm in length, while their larvae strike using raptorial appendages that are only 1 mm in length. Making use of this impressive size range, we examined the scaling of morphology and kinematics of the elastic mechanism in adult and larval mantis shrimp raptorial appendages. We filmed raptorial appendage strikes in larval Philippine mantis shrimp (*Gonodactylaceus falcatus*; 2 animals, 6 strikes) and found that they accelerate at an average of $1.6x10^5$ rad/s^2 with a maximum angular velocity of 308 rad/s, similar to adult strikes. However, the speed of larval strikes (0.33 m/s) is slower than adult mantis shrimp (2.1-20.2 m/s). We also examined the morphology of larval raptorial appendages using microCT scans and compared them to adults. Adult mantis shrimp use muscles to store elastic energy in the merus exoskeleton, while internal latches release the strike. We found that larvae possess similar muscle and latch arrangements as adults, which suggests that larvae also store and release elastic energy using a spring and latch mechanism. By establishing strike kinematics and morphology of larval mantis shrimp, we offer insights into the scaling of the mantis shrimp elastic energy storage mechanism.

18-7 HART, P. B.*; NIEMILLER, M. L.; BURRESS, E. D.; ARMBRUSTER, J. W.; CHAKRABARTY, P.; Louisiana State University, University of Alabama, Huntsville, University of California, Davis, Auburn University; *pamelabeth.hart@gmail.com*

Phylogenomics and Shape Variation Among Amblyopsid Fishes

Cave-obligate organisms long have captured the imagination and interest of scientists and the general public, yet their evolutionary histories and modes of subterranean adaptation remain poorly understood. The endemic North American fishes in the family Amblyopsidae are one of very few families across the ray-finned fish Tree of Life to contain both surface- and obligate cave-dwelling members; thus, this group is ideal for comparative studies of cave adaptation. Morphological and molecular datasets have presented conflicting evolutionary relationships within the Amblyopsidae, particularly with respect to the placement of eyed species in relation to the blind, cave-obligate taxa. To further elucidate phylogenetic relationships within the Amblyopsidae, we collected genomic data from over 800 ultraconserved element (UCE) loci from 119 samples representing all described taxa as well as additional undescribed lineages. All three states of cave adaptation (surface, facultative-cave, and obligate-cave forms) were sampled. In addition to phylogenomic analysis, we performed an ancestral state reconstruction. Lastly, we assessed how shape variation fit into the larger picture of cave adaptation using geometric morphometrics to quantify body shape differences among amblyopsid species. We recovered each of the eyed fishes as sister to an eyeless cavefish and our ancestral state reconstruction supported an eyeless, cave ancestor at the base of the family, indicating possible independent eye redevelopment in *both* of the eyed fishes. It also appears that cave adaptation or eye redevelopment leads to changes in body shape. However, we remain healthily skeptical of these results and will perform further analyses. This work will provide insight into the patterns and modes of cave adaptation.

P1-106 HARTLEY, JG*; GOMES AVERSA, MD; LEESE, JM; DeSales University; *jh6817@desales.edu*

Female mate preference influenced by intrasexual competition and differences in male quality

Sexual selection, the ultimate mechanism driving the evolution of sexual dimorphism in plants and animals, includes both intra and inter-sexual components. Exploring the interaction of these forces is difficult and most experimental studies tend to focus on one aspect or the other. Here, we set out to explore the interaction between intra- and inter-sexual selection pressures on mate preference in a monogamous model system. Two female convict cichlids, *Amatitlania siquia*, were placed into an experimental aquarium containing two compartments with a potential male mate and nest site in each, and a central neutral compartment. The females could freely move between compartments and interact with potential male mates, as well as each other, for a three-day observation period. This design allowed for simultaneous intrasexual competition between females as well as the formation of a preference between two males of similar quality. In a second experiment, the same design was used, but the two males differed in quality. We found that females demonstrated a time-based preference for males in both experiments, but that in the first experiment (size-matched males), there was no difference in preference between the two males; each female seemed to prefer one of the males. In the second experiment (size difference males), however, both females demonstrated a preference for the large male. This was evidenced by females spending significantly less time with the smaller male by the end of the experiment. This suggests that in the presence of intrasexual female competition, females may adjust their threshold for potential mates, even to the extreme level of foregoing reproduction with a low-quality male when a higher quality male is unavailable. Future work will explore how levels of female aggression may be affected by differences in male quality in this experimental paradigm.

P3-89 HARTMAN, R. A.*; GRIESBACK, K.; SCOTT, K. S.; TOBE, S.; LANDBERG, T.; Arcadia University; *ryan.hartman007@gmail.com*

Heavy metal contamination of common snapping turtles in the Lower Delaware River watershed

The common snapping turtle (Chelydra serpentina) is a long lived reptile that tolerates tremendous amounts of pollution. Because of this, they have been used as indicators to monitor toxicity of their environment. The industrial history of the Philadelphia area as a manufacturer of steel and paper milling led to highly polluted waterways which suggests that the snapping turtles of the region are contaminated with heavy metal pollutants such as zinc, mercury and lead. While zinc is an essential element for humans, there are no known safe levels of lead consumption. This poses a potential health risk as snapper soup is a Philadelphia regional delicacy served in restaurants for hundreds of years and trapping turtles for consumption is legal. We examined the heavy metal content of tissue samples of C. serpentina (n= 47 claw clippings from living and additional muscle samples from road-killed turtles) collected in a ~900 square mile area around Philadelphia. Atomic absorption spectroscopy showed detectable heavy metal concentrations in all the samples. As expected, claw tissues of C. serpentina varied dramatically in zinc concentration across sites indicating that local conditions and historical pollution determine metal content. Keratin tissue (AVG= 1351.66µg/g, SD=2292.39µg/g, n=20) showed significantly higher zinc content than muscle (AVG=57.32µg/g, SD=14.59µg/g, n=2). Analysis for lead and mercury are still being investigated. Since turtles throughout the lower Delaware River watershed may have extreme metal concentrations in their tissues, eating turtle flesh from this area may be dangerous to humans in addition to being detrimental to turtle populations already potentially stressed by habitat degradation.

P2-237 HARTWICK, MN*; REICHMUTH, C; THOMETZ, NM; University of San Francisco, University of California, Santa Cruz; *mnhartwick@dons.usfca.edu*

Evaluating Seasonal Changes in Body Condition for Spotted, Ringed, and Bearded Seals

Arctic seals must manage considerable seasonal changes in sea ice coverage, air and water temperatures, photoperiod, and prey availability. These species utilize blubber for onboard energy storage, thermoregulation, streamlining, and buoyancy, and this insulating layer changes in thickness and composition throughout the year. Specifically, seals rely on blubber as a critical energy reserve during physiologically taxing life-history stages such as breeding, lactation, and molt. Blubber thickness, along with complementary morphometric measures, can be used to assess overall body condition in seals. We used a modified truncated cones method to track within-individual, fine-scale changes in the body condition of three species of Arctic seal. Our study animals included 4 spotted seals (*Phoca largha*), 3 ringed seals (*Pusa hispida*), and 1 bearded seal (*Erignathus barbatus*) trained to participate in research procedures at two facilities in California and Alaska. We used a portable ultrasound machine to measure blubber thickness at 12 sites along the length of each animal. We used photogrammetric methods to measure standard length, curvilinear length, and body heights using scaled photographs. In addition, we collected direct measures of body length, girth, and mass. Ultrasound, photogrammetric, and direct morphometric data were collected weekly for a minimum of one year. Using a modified truncated cones method, seals were modeled as a series of consecutive cones in which the inner core represented lean mass, and the outer layer represented blubber mass. Separating lean mass and growth from dynamic changes in overall body condition enabled assessment of critical periods when seals are most reliant on blubber energy reserves.

79-6 HASSANALIAN, M*; WALDROP, L; BAKHTIYAROV , S; New Mexico Institute of Mining and Technology; *mostafa.hassanalian@nmt.edu*

Thermal impacts of body colorization of marine animals on their skin friction drag

There is an increasing need for doing research in drag reduction and performance enhancement techniques. Since the nature has developed processes, materials, and the functions to increase its efficiency, it has the best answers when we seek to improve or optimize a system. One of the sources for inspiring the drag-reduction methods and performance enhancement is biological aquatic systems which can be studied for their desirable properties. One of the methods in drag reduction applied by warm-bodied aquatics, such as marine mammals, scombrid fishes, and sharks is boundary layer heating. These organisms have the capacity to use heat conducted from the body surface to decrease water viscosity around their body and consequently reduce the drag. In this work, a new factor which is affecting the boundary layer of some aquatics and subsequently their skin drag reduction will be studied. The thermal effects of body color of marine organisms will be investigated in some species, such as whales, manta rays, dolphins, penguins, sharks, seals, and sailfish that have black color at the top and white color at the bottom sides of their respective bodies. Considering the marine and water characteristics of the mentioned species, a thermal analysis will be performed in this study, when these aquatic animals are in motion under the water. The surrounding fluxes including the water flux and the sun irradiation inside the water are considered in an energy balance to determine the skin temperature of both sides of the organisms' body. Applying the Blasius solution and computational fluid dynamics methods for heated boundary layers, it will be shown, that the black color on the top and the white color on the bottom side of the bodies of these marine organisms is very efficient in terms of skin drag reduction.

P2-49 HASSERT, JC*; STAHL, A; BUSCHBECK, EK; University of Cincinnati, Scripps Florida Society of Research Fellows; *Hasserjc@mail.uc.edu*

Gaining Focus: Using RNAi to Understand How T. marmoratus Larval Eyes Maintain Focus

Visual systems are complex and require that all pieces work together to form clear images. The refractive power of the lens is fundamentally important for any eye to maintain correct focusing. During growth, all parts of the eye need to coordinate to maintain focus. Previous studies have thoroughly examined how vertebrates can preserve this property during their growth, but there are few studies which attempt to answer the question in invertebrates. Unlike vertebrates which grow gradually, insects must undergo ecdysis—shed their outer layer, including their lenses. This presents a unique evolutionary challenge to overcome: how do you maintain correct focus with rapid eye growth? An excellent model for eye development are Thermonectus marmoratus larvae which have exceptional eyes that use a bifocal lens to focus images on two retinas. These larvae undergo rapid growth between their 2nd and 3rd larval stages and substantially reform their lenses to accommodate this growth. The cuticular protein Lens3 is a major contributor to the lens. In this project we use RNAi to knock down Lens3 expression and to investigate if reduction of this major lens protein leads to refractive errors, or if T. marmoratus eye development contains compensatory mechanisms that allow correct focus to be maintained. Knockdowns can be measured using a customized ophthalmoscope to determine focusing abilities. This study will provide insights towards the question of whether invertebrates use active or passive regulation to maintain focus.

P2-46 HAVENS, LT*; KINGSTON, ACN; SPEISER, DI; UNC Chapel Hill, USC Columbia; *lukethavens@gmail.com*

A novel, automated approach to electroretinography

Understanding the physiological limits of an animal's visual system is an important part of studying its visual ecology. Without first determining what an animal is physiologically capable of sensing, 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 often involves its own skillset, ERG can require expertise beyond that necessary for the electrophysiological preparation itself. To improve both the efficiency and accessibility of ERG, we designed a highly automated system for both stimulus presentation and data acquisition. Rather than relying on manual adjustment of stimuli and real-time comparison of response, our system automatically adjusts the intensity of all light stimuli to specified photon flux. In addition, light control can be achieved through a series of prompts, allowing users to set up and run automated trials after answering a set of basic questions about the experiment. Here we test this novel system's ability to accurately assess spectral sensitivity in the well characterized visual system of the crayfish using both existing magnitude of response and novel temporal acuity based techniques, where higher magnitude of response and temporal acuity denote greater sensitivity. Using this system, we find that we are able to acquire highly accurate, reproducible results in ERG experiments quickly and with minimal training beyond introduction to electrophysiology.

S6-5 HAVIRD, JC; Univ. of Texas, Austin; *jhavird@utexas.edu*
Mitonuclear Ecophysiology: The Cooperative Genomics of Environmental Adaptation
Eukaryotes sustain the energy necessary to maintain cellular function through the coordinated actions of genes found in two different genomes: the nuclear and mitochondrial (mt) genomes. It follows that energetically expensive physiological processes such as thermoregulation depend on preserving the precise interactions between nuclear- and mt-encoded gene products. Mitonuclear coevolution is therefore an enduring feature of eukaryotes and is especially important for ecophysiology. Combining molecular approaches to characterize mitonuclear coevolution with physiological studies that characterize the role of mitochondria in environmental adaptation is intriguing (i.e., "mitonuclear ecophysiology"). Here, I present data from three systems that attempt to take such an approach: 1) characterizing mt physiology of cold-adapted aquatic insect larvae during thermal acclimation, 2) assessing mt function in an angiosperm with atypical mt mutation rates and genome sizes, and 3) looking for signatures of mitonuclear coevolution in tissue-specific paralogs with different energetic requirements in both vertebrate and invertebrate systems. It is hoped that new tools in genomics, modeling, and biochemistry will facilitate more refined studies along these lines. Extending such thinking to plastids and other endosymbionts is another obvious goal, as well as integrating these ideas with the role of cytonuclear interactions in classic evolutionary ecology concepts such as speciation and sex.

133-5 HAWKINS, TM*; MARSHALL, AS; SHORT, RA; WOLFORD, AM; DAVIS, JE; Radford University; *thawkins18@radford.edu*
Effects of Royal Jelly and Juvenile Hormone on Growth and Immunity in Gromphadorhina portentosa and Drosophila melanogaster
Growth hormones play a key role not only in control of development but also in regulation of immune function; investment in reproduction and somatic growth may also come at the cost of resources allocated to immune function. Previous research has focused primarily on endocrine modulation of immune function in vertebrates. Here I will describe hormonal influences on investment patterns in immunity, growth and reproduction in several species of insects. Royal jelly (RJ), a modulator of reproduction and growth in honeybees, has been shown to induce similar effects in fruit flies (*Drosophila melanogaster*). Specifically, flies reared with royal jelly experienced hastened turnover time from youth to functioning adult and increased ovary size. Similar effects of RJ exposure have been observed in Madagascar hissing cockroaches (*Gromphadorhina portentosa*). In contrast, juvenile growth hormone (JH) maintains adolescent morphology and physiology in juveniles and increases reproductive output (via vitellogenesis) in adults across a wide variety of invertebrate taxa. However, studies in our lab have shown inconsistencies in the effects of JH exposure on hissing cockroaches and fruit flies in terms of both mortality and reproduction. In addition, JH given in combination with RJ produced distinctly different effects on both sex traits and reproductive patterns across species. In addition we explored the specific impacts of RJ, JH and RJ+JH on immune functions, as measured by lytic and coagulatory activity, in invertebrates. We will discuss the implications of our findings for both our understanding of hormonal control in invertebrates and consequences of variable energy strategies across systems and taxa.

P2-243 HAWKINS, RK*; BELL, CJ; STOCKER, MR; Virginia Tech, University of Texas at Austin; *rehawk@vt.edu*
Intraspecific Variation in the Cranial Osteology of Diplometopon zarudnyi
A snake-like body plan and burrowing lifestyle characterize countless vertebrate groups through convergent evolution. One such group is the amphisbaenians, a limbless clade of lizards that are primarily fossorial and exhibit head-first burrowing behavior. Correlated with this behavior, amphisbaenian skulls are recognized as more rigid and coossified than those of non-burrowing lizards. However, due to their elusive lifestyle, amphisbaenian skulls are not yet well understood, including how cranial osteology may vary among individuals of the same species and what that reveals about constraints on skull morphology of head-first burrowing taxa. We investigated intraspecific variation in the cranial osteology of amphisbaenians using *Diplometopon zarudnyi*. Variation among skull and skull element morphology was analyzed qualitatively and by performing 3D landmark-based geometric morphometrics on 3D models created from microCT data. Significant differences were observed in the length of dorsal contact between the parietal and occipital complex, the interdigitation of the frontals and parietal, and the degree of coossification between the occipital complex, fused basioccipital and parabasisphenoid, and Elements X. These results reveal significant variation in suture interdigitation and morphology of the occipital region in *D. zarudnyi*, indicating that the variation may be the result of different stages of ontogenetic development or that these regions may have less strict morphological constraints in head-first burrowing taxa. Examination of this variation across other head-first burrowing taxa will help determine if this is clade-specific or part of a broader macroevolutionary pattern.

P1-38 HAWKINS, O. *; TACK, N. ; DU CLOS, K. ; GEMMELL, B. J. ; University of South Florida; *hawkinso@mail.usf.edu*
Does the wing-like shape of an oceanic plankton predator provide hydrodynamic camouflage?
Ctenophores or comb jellies are known to be important marine predators that can alter plankton community dynamics in coastal ecosystems. Open ocean ctenophores are ubiquitous but poorly understood due to their delicate, gelatinous nature. *Cestum veneris*, or the venus girdle, is a very unusual ctenophore that exhibits a compressed, wing-like morphology, differing greatly from other gelatinous zooplankton. This animal continuously glides through the water propelled by ciliary ctene rows at the rear of the wing. *C. veneris* primarily preys on hydrodynamically sensitive copepods capable of responding to minute fluid disturbances with powerful escapes. However, there is currently little information on *C. veneris* feeding ecology. In order to determine if the unique wing-like morphology of *C. veneris* is capable of masking the hydrodynamic signal given off to copepod prey, we recorded the interaction of the copepod *Acartia tonsa* as they approached a 3D analog of the wing in a laminar flow water channel. We found that at low simulated swimming speeds copepods always detected and avoided contact with the wing. However, as speed increased, the reaction distance of the copepods relative to the wing decreases. At naturally observed swimming speeds, direct copepod contact with the wing could be observed. Quantification of fluid deformation rates around the wing and comparison of copepod response locations suggest that at natural swimming speeds, the wing-like morphology of *C. veneris* provides hydrodynamic stealth to aid in capturing sensitive prey.

P2-167 HAWTHORNE-MADELL, J; LIVINGSTON, K; AARON, E; LONG, JH*; Vassar College, Colby College; *jolong@vassar.edu*

Developmental Error Increases Genetic Variation in Evolving Robots

Because genetic variation is required for adaptive evolution, it is essential to understand the mechanisms that maintain it in the face of selection. Although genetic errors such as mutation are primary, here we demonstrate another independent mechanism for maintaining genetic variation in populations: random epigenetic errors in development. We simulated populations of mobile, autonomous robots in which genomes encode morphological and neural structures, spatial relations, and regulatory elements; the interactions of structures and regulatory elements unfold in an explicitly modeled developmental process. Our system also explicitly models random genetic errors and random developmental errors. We simulated 11 levels of genetic error rate, 11 levels of developmental error rate, and their interactions in 10 populations of 60 simulated robots over 100 generations, with fitness determined by a simple movement task. In the presence of directional selection, genetic variation was proportional to the rate of random developmental error. Moreover, random developmental error and random genetic error are separate and independent mechanisms, as demonstrated by their statistical independence over evolutionary time. In addition, at all levels of developmental error, the mean individual fitness increased over generational time. This model therefore is consistent with the prediction that random developmental error is an evolutionary mechanism that maintains genetic variation, which, in turn, enables sustained adaptive evolution. This work was funded by the U.S. National Science Foundation (grant no. 1344227, INSPIRE, Special Projects).

S6-11 HEALY, TM; MCKENZIE, JL; CHUNG, DJ; BRENNAN, RS; WHITEHEAD, A; SCHULTE, PM*; SCHULTE, Patricia; University of British Columbia, University of California, Davis; *pschulte@zoology.ubc.ca*

Mitochondrial physiology, mitonuclear interactions, and adaptation to environmental stressors

Mitochondria act as a major hub coordinating responses to environmental stressors. Atlantic killifish, *Fundulus heteroclitus*, provide a useful model in which to examine the role of mitochondria in these responses in an evolutionary context. This species is found in marshes along the Atlantic coast of North America, through a steep latitudinal thermal gradient. The northern and southern subspecies of killifish differ in mitochondrial genotype, mitochondrial physiology, and in many whole-organism traits that may be involved in adaptation to their respective environments, including metabolic rate, thermal tolerance, and hypoxia tolerance. Fish with northern and southern mitochondrial genotypes meet and interbreed along the coast of New Jersey and within the rivers of the Chesapeake Bay, resulting in replicate hybrid zones across which there is a steep transition from one mitochondrial type to another. This provides an opportunity to assess the role of mitonuclear interactions in the response to environmental stressors. Genome wide association studies of traits such as thermal tolerance, hypoxia tolerance, and metabolic rate in these hybrid populations point to an important role for genes regulating mito-nuclear communication and cellular metabolic processes. However, there is no association of these traits with variation in the mitochondrial genome, and little evidence of genetic incompatibility between the mitochondrial genome and nuclear-encoded mitochondrial genes. Interestingly, there is some evidence of developmental failure in crosses between southern females and northern males, suggesting a potential role for intrinsic genetic incompatibilities in the maintenance of these hybrid zones.

69-7 HEDRICK, BP*; DUMONT, ER; PIERCE, SE; Univ. of Oxford , Univ. of California, Merced, Harvard Univ.; *bphedrick1@gmail.com*

The Evolutionary Success of Rodents Is Not Linked to the Evolution of Locomotor Innovation

Rodents are the most species-rich order within Mammalia and they have evolved a wide variety of morphologies to accommodate numerous locomotor niches, ranging from gliding squirrels to fossorial pocket gophers. They provide an excellent opportunity to understand how locomotor innovation can drive speciation. To evaluate the connection between the evolutionary success of rodents and the diversity of rodent locomotor ecologies, we used humerus and femur CT scans from 76 species across Myodonta and the Heteromyidae to examine internal and external limb shape. Internal morphology was quantified using cross-sectional geometric parameters and external morphology was quantified using 768 pseudo-landmarks applied to bone surfaces. Based on these data, only fossorial rodents displayed a major reworking of their proximal limb elements in both external and internal morphology with other locomotor modes plotting closely with terrestrial rodents. Fossorial rodents were also the only locomotor mode to consistently show increased rates of morphological evolution in both internal and external shape. There was no correlation between internal and external shape of the proximal limb elements, suggesting that internal and external morphology are decoupled. These results together suggest that only extreme locomotor shifts (i.e., fossoriality) require a substantial reorganization of proximal limb elements away from the terrestrial rodent bauplan. Additionally, there appears to be a decoupling of rates of speciation and rates of proximal limb morphological evolution. We propose that rodents have been so successful at evolving into new niches and colonizing new areas due to high locomotor plasticity, which allowed them to modify their locomotor mode without requiring major bauplan modifications.

106-2 HEDRICK, AR*; GREENE, DU; LEWIS, EL; HOOD, AS; IVERSON, JB; Iowa State University, Texas Tech University , Utah State University , Earlham College; *hedrick@iastate.edu*

Climate Effects on Nesting Phenology in Nebraska Turtles

Rising temperatures resulting from climate change instigate the advancement of reproductive phenology in a variety of organisms across the globe. These phenological shifts have profound impacts on thermal tolerance and breeding ecology and can promote asynchronies between interacting species. However, reptiles are vastly underrepresented in such studies and much work is still needed to understand how these changes will impact phenology in these organisms. Since 1981, we have monitored reproductive activities of three fresh water turtle species, the Yellow Mud Turtle (*Kinosternon flavescens*), the Western Painted Turtle (*Chrysemys picta*), and the Common Snapping Turtle (*Chelydra serpentina*), at our western Nebraska study site. During these years, average annual air temperatures at the site have increased at a rate greater than 0.4 C per decade. Nevertheless, the timing of nesting (whether first nest or mean/median nest) in all three species of turtles, has remained relatively unchanged. We find that nest timing in each species was highly correlated with spring day-time temperatures, which have not increased substantively at our study site over the past four decades; instead, the ambient temperature increase is mostly due to increases in mean daily minimum temperatures. Thus, should climate change eventually increase spring day-time temperatures, nesting phenology should respond inversely, which could impact recruitment rates by shifting nesting emergence date and could also have downstream effects on nest predators that rely on the predictability of turtle nesting as a food source.

S12-7 HEEPE, Lars*; GORB, Stanislav/N.; Kiel University, Germany; *lheepe@zoologie.uni-kiel.de*

Gecko adhesion or "gecko effect" adhesion? A case for comparative studies among lizards, spiders, and insects

Representatives of several animal groups such as insects, arachnids, and lizards are able to attach to and to walk on smooth vertical surfaces and even on the ceiling. This ability is due to highly specialized fibrillar attachment devices located at their legs. The biomimetic transfer of such systems into industrial applications is a very challenging task, since biological systems are far too complex for copying them exactly. That is why intensive comparative studies are required to find out which structural and mechanical features of real biological systems are essential for biomimetics. In general, there are two different working strategies that aid in extracting that features of biological objects. The first strategy is based on a careful and detailed characterization of one particular biological system defined as a model object, here for example geckos. The second strategy is based on a comparative study of a large variety of biological objects, which possess similar functional systems that appeared independently in the course of biological evolution. In our opinion, the second approach is more promising for biomimetics, because structural similarities, which evolved independently in different lineages of organisms, may indicate some kind of "optimal" solution for this type of system. Moreover, a comparative approach aids in extracting essential features and abandoning less important ones for designing artificial adhesives. Although different, these two approaches are complementary and help in the biomimetic process.

P2-180 HEFELE, KR*; CELEC, S; JORGENSEN, DD; Roanoke College, Roanoke College ; *krhefele@mail.roanoke.edu*

Cardiac Function in the American lobster: How Does Pericardial Sinus Pressure Relate to Pressure Inside the Heart?

The American lobster (like other decapod crustaceans) employs a single pumping chamber, the ventricle, to push hemolymph into an arterial tube network. The ventricle (V) is suspended in a space, the pericardial sinus (PS), by an array of suspensory ligaments. Hemolymph returning from the tissues passes through the gill circulation, is collected in the PS, and moves from the PS into the V during ventricular relaxation through three pairs of openings (called ostia) located in its dorsal, lateral, and ventral walls. However, the exact mechanism of ventricular filling is not well understood. In this study we investigated hydrostatic pressure distribution in the PS in relation to ventricular lumen pressure over the cardiac cycle. Hemolymph pressure was measured continuously in the ventricular lumen and in different locations in the PS in quiescent animals. The digitized pressures were overlaid electronically and the integrated difference between V and PS pressures was expressed as the cardiac filling index (Pa·sec). We also investigated how the cardiac filling index (CFI) changes during periods of higher metabolic demand (while the animals walked on a submerged treadmill) when heart rate (HR) is elevated. We found a significant difference between CFI when comparing rest and exercise conditions (34.3 Pa·sec and 21.5 Pa·sec respectively; n=5). CFI decreased with increased HR during exercise. We found that hemolymph pressure is not homogeneous throughout the PS, and therefore CFI varies within these different regions of the PS. These observed differences likely owe to the complex geometry of the PS. We suggest that some ostia may be more important in the ventricular filling process because PS pressure is not homogeneous in this space.

S5-1 HEIDINGER, Britt*; WADA, Haruka; WADA, Haruka; North Dakota State University, Auburn University; *haruka@auburn.edu*

A brief introduction to the symposium

Most organisms initiate a highly conserved ‘stress response' in the face of environmental and social stressors. Assumptions are that variation in the way in which individuals respond to stressors has important fitness consequences. However, in the last decade, these assumptions have been questioned. For example, individual variation in baseline and stress-induced levels of glucocorticoids predicts survival or reproductive success only in some cases. One primary reason behind this equivocal relationship between well-conserved organismal stress responses and fitness-related measures is the effects of stress hormones are often context- and condition-dependent. Thus, there is a dire need to understand how stress responses are integrated across levels of biological organization to form ‘the stress phenotype'. Towards this end, the goal of this symposium is to bring together researchers from diverse backgrounds that study the stress response across levels of organization (i.e., molecular, cellular, and organismal biology) to share findings and foster collaborations to better understand the integrated stress response from genomes to phenomes. An enhanced understanding of the integrated stress response has important evolutionary implications and is critical for predicting how organisms will respond to climate change and increasing human perturbation. The symposium will begin with a brief introduction by organizers.

90-1 HEINE, KB*; POWERS, MJ; KALLENBERG, MC; TUCKER, VL; HOOD, WR; Auburn University, Auburn, AL; *kbh0039@tigermail.auburn.edu*

Moderate UV-B Irradiation Increases Fecundity but Decreases Longevity in a Marine Copepod

Mitochondria are thought to have a biphasic response to the production of reactive oxygen species (ROS), where low levels of ROS benefit mitochondrial performance and high levels are damaging. Based on a previous study that showed a significant increase in ROS production under three-hour UV-B exposure in Antarctic and temperate copepods, we hypothesized that such a moderate oxidative event leads to more advantageous life history characteristics. Using UV-B light as an oxidant to induce moderate ROS production in *Tigriopus californicus* copepods, we measured the impact of UV-B exposure on fecundity and longevity in female copepods. Treatments included an unexposed control and both one and three-hour UV-B exposure (0.5 W/m^2) during mate guarding. We found that moderate UV-B exposure resulted in higher fecundity, associated with an increase in size of the first clutch, and a decrease in longevity among all females that mated. UV-B exposure had no effect on whether females produced clutches. Gestation duration and size of the first clutch were inversely related. Females that did produce clutches lived longer, and among breeding females, the number of clutches that a female produced increased with her longevity. UV-B exposure had no significant effect on gestation duration of the first clutch or on the number of clutches that a female produced. These findings indicate a benefit to moderate UV-B exposure, where individuals exposed to moderate oxidation may have an increased capacity to reproduce, at least early in their reproductive life.

117-3 HEISS, E*; SCHWARZ, D; KONOW, N;
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Flexibility of intraoral food processing in newts

Intraoral food processing refers to any form of mechanical reduction of food within the mouth prior to swallowing. Processing mechanisms are known for all major vertebrate clades, but the form and function of systems used to crush, grind, or puncture food items differ substantially between as well as within major clades. In most vertebrates, mechanisms of intraoral processing display flexibility and can be adjusted to demands of different environmental conditions or food types. Recently, we described a peculiar processing mechanism in newts and showed that they use cyclic loop-motions of the tongue to rasp prey against the palatal dentition. However, it is not known if newts can modulate their processing behavior in response to different conditions. Newts provide interesting models for studying functional modulation in response to different conditions due to their unique and flexible lifestyle: Newts seasonally change between aquatic and terrestrial habitats and consume a wide range of food types. Here, we test the effects of (i) the medium where feeding occurs (water/air) and (ii) food type (maggot, earthworm, cricket) on the processing behavior in the newt *Triturus carnifex*. Using x-ray high-speed recordings, anatomical investigations and behavioral analyses, we demonstrate that newts show little change in food processing between aquatic and terrestrial feeding. However, they adjust the number of processing cycles to different prey types. For example, while maggots are processed extensively, earthworm pieces are swallowed nearly unreduced. We conclude that sensory feedback such as smell, taste and material properties induce flexible processing responses, while the medium where feeding occurs appears to have less of an effect.

71-3 HENDERSON, KW*; HALE, ME; Univ. of Chicago;
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Whole fin neural mapping uncovers complexity of sensory architecture and function

The optical clarity, extensive genetic toolkit, and small size of the larval zebrafish make it amendable to explorations of neuromechanical form and function. Here, we apply these approaches to investigate the sensory architecture of the pectoral fin and consider its relationship to function. We mapped the full extent of the sensory innervation of the fin, the first time this has been done in the limb of a vertebrate. We stochastically labeled the mechanosensory Rohon-Beard cells (RBs) by injecting UAS:ptagRFP into isl2b:Gal4 embryos, imaged these at 5dpf with confocal microscopy, and reconstructed single neurons. We found that a subpopulation of islet2B$^+$ RBs located at the level of the fourth and fifth myomeres innervate the pectoral fin. These cells display classic RB morphology with dense primary afferent arborization. Unexpectedly, RBs that innervate the fin also innervate the body. In the fin, RB processes innervate abductor, adductor, or occasionally both surfaces of the skin. The degree of innervation of the fin varied between RBs, with some cells branching to cover a large area of the fin while others projected into smaller regions only at the base. We hypothesized that there would be increased innervation at the level of the blood vessel, a previously described point of bending where the musculature at the base of the fin gives way to the membranous distal portion of the fin; however, we find no evidence of increased density in the bending "joint." The variation of innervation fields within the fin, in combination with axial innervation, suggests a complexity of sensory information processing at the level of single RBs and across the population. This work provides a basis for more direct interrogation of function as well as possible comparative studies between vertebrates and invertebrates.

43-6 HENSCHEN, A.E.*; ADELMAN, J.S.; Iowa State Univ., Iowa State Univ. ; *henschen@iastate.edu*

Investigating the evolution of tolerance in a wild songbird

Mechanisms that reduce the costs of infection are expected to evolve when populations encounter novel pathogens. Individuals can reduce the costs of infection in two main ways: resistance and tolerance. Resistance decreases the costs of infection by decreasing pathogen load. In contrast, tolerance does not result in decreased pathogen load but rather the per-pathogen cost of infection. Most work in animals has focused on resistance, but we hypothesize that tolerance should evolve in host-parasite systems where resistance itself is very costly (e.g., due to strong inflammatory reactions that can damage host tissues). We tested this hypothesis in several populations of house finches (*Haemorhous mexicanus*) in which the bacterial pathogen *Mycoplasma gallisepticum* (MG) has been endemic for different amounts of time. Finches infected with MG display strong inflammatory immune responses and severe conjunctivitis, impairing predator avoidance and reducing survival probability. To determine if tolerance to MG has evolved in house finches, we measured pathogen load and the severity of conjunctivitis after experimentally infecting individuals from four populations with different histories of MG endemism. We predicted that, when infected with the same pathogen load, individuals from populations that have been coevolving with MG for a greater amount of time (>20 years) would have less severe conjunctivitis than individuals from populations that have been coevolving with MG for less time (5-10 years), or those from populations naïve to MG. This work allows us to determine if, and how quickly, tolerance to a pathogen can evolve and whether tolerance repeatedly evolves in different populations faced with the same novel pathogen.

73-2 HENSLEY, NM*; ELLIS, EA; GERRISH, GA; TORRES, E; FRAWLEY, JP; OAKLEY, TH; RIVERS, TJ; Univ. of California, Santa Barbara, Univ. of Wisconsin, La Crosse, California State Univ., Los Angeles, Univ. of Wisconsin, La Crosse, Univ. of Kansas; *nikohensley@gmail.com*

Phenotypic evolution shaped by current enzyme function in the bioluminescent courtship signals of sea fireflies

Mating behaviours are diverse and noteworthy, especially within species radiations where they may contribute to speciation. Studying how differences in mating behaviours arise between species can help us understand how diversity is generated at multiple biological levels. The bioluminescent courtship displays of cypridinid ostracods (or sea fireflies) are an excellent system for this since amazing variety evolves while using a conserved biochemical mechanism. We find that the evolution of one aspect in this behavioural phenotype - the duration of bioluminescent courtship pulses - is shaped by biochemical function. First, by measuring light production from induced bioluminescence in 38 species, we discovered differences between species in their biochemical reactions. Then, for 16 species of which biochemical, phylogenetic, and behavioural data are all available, we used phylogenetic comparative models to show that differences in biochemical reaction are nonlinearly correlated with the duration of courtship pulses. This relationship indicates that changes to both enzyme (c-luciferase) function and usage have shaped the evolution of courtship displays, but that they differentially contribute to these phenotypic changes. This nonlinear dynamic may have consequences for the disparity of signalling phenotypes observed across species, and demonstrates how unappreciated diversity at the biochemical level can lead to inferences about behavioural evolution.

32-1 HERBERT, A*; SUMMERS, A; WILGA, C; U Alaska, U Washington; *aherbert3@alaska.edu*

Morphology of the Jaws and Tooth Plates in Spotted Ratfish

The subclass Holocephali (chimaeras) is comprised of deep-water cartilaginous fishes and is the sister group to Elasmobranchii (sharks, skates, rays). The jaws and tooth plates of chimaeras diverged from elasmobranchs in shape and structure. Chimaeras have a holostylic jaw suspension (upper jaw fused to the cranium) and 3 pairs of tooth plates. In contrast, elasmobranchs have a hyostylic jaw suspension (mobile upper jaw) and individual or tightly interconnected teeth. There are 3 extant families of holocephalans, and of the extinct holocephalans, the fossils contain only tooth plates and spines. As a result, holocephalans are primarily classified on tooth plate characteristics. In *Hydrolagus colliei*, the tooth plates are thin and vertically aligned with the anterior plates forming a beak, and the diet contains a range of hard and soft prey. How *H. colliei* are able to feed on such a diversity of prey and how their distinct tooth plates function during feeding is perplexing. The tooth plates of *H. colliei* were analyzed for shape variation using 2D and 3D geometric morphometrics. Also, the second moment of area (*I*) was calculated for the lower jaw using CT scans. This revealed that tooth plate shape varies greatly within species and even among individuals of similar lengths. The lower jaw has a higher *I* in the posterior half compared to the anterior half. The values for *I* in the posterior half imply that this is where *H. colliei* cracks or crushes prey and are comparable to durophagous elasmobranchs. Examining the tooth plates of other holocephalans may reveal that species share a general tooth plate shape, but the variation appears in the details: edge outline, height, tritors, grooves. This suggests that while shape and structure of the feeding apparatus can be specialized in chondrichthyes, the function can be generalized.

P2-207 HERBST, HD*; PORTER, ME; Florida Atlantic University; *hherbst2015@fau.edu*

Impacts of denticle density: Quantitative analyses of marine fouling on shark skin

Marine fouling is the settlement of microorganisms on wet surfaces. Many studies have designed structures that mimic the microscopic patterns of dermal denticles on shark skin to prevent marine fouling. For example, industrial surfaces inspired by shark denticles reduced marine fouling and decrease bacterial growth by up to 87%. However, we found no quantitative evidence to justify the claim that shark skin is antifouling. This study quantifies marine fouling on shark skin from the blacktip shark (*Carcharhinus limbatus*) along dorsal and ventral surfaces, which provided a range of denticle densities and varying morphology. We hypothesized that significant growth would occur on control and shark skin surfaces during the 120 hour experimental period. We also expected to find increased percent cover where denticle density was lowest. Shark skin and control samples, sterile petri dishes, were exposed to agitated flow-through seawater and daylight cycles for 120 hours (five days). We quantified fouling every 24 hours by removing the surface from water flow, photographing, and then using NIH ImageJ to quantify percent cover. When control surfaces were exposed to seawater conditions, significant growth (more than 30% cover) was present after a 24 hour time period. At 24 hours of exposure, shark skin showed less than 0.01% growth and on average there was only 1.7% cover at the end of the 120 hour experimental period. We showed that percent cover over time increased as denticle density increased. These data suggests that denticle density plays a key role in preventing fouling, as denticle presence led to significantly less microorganism settlement over time when compared to a control. Future research will be conducted to determine if shark skin prevents bacterial growth and if denticle morphology impacts fouling.

P2-265 HERBST, K*; SCOTT, K; LANDBERG, T; Arcadia University; *kherbst@arcadia.edu*

Effects of Drug and Rat Body Part on the Growth of Necrophagous Beetle Dermestes maculatus

Observing arthropod colonization on bodies can provide investigators with valuable information on post mortem interval (PMI). Blow flies colonize bodies rapidly and are forensically useful on relatively fresh remains however necrophagous beetles with slower development may be more useful in cases with longer PMI. However, diet affects growth and in cases of drug related deaths, insects may experience second hand drug effects. Based on blow fly research we expected a depressive effect of both ketamine and xylazine on growth and development. Further, higher fat content in meat types was predicted to increase growth rate and decrease time to metamorphosis. We tested the effects of these drugs in different doses and combinations on beetle development over 9 weeks in 6 body regions (arms, legs, 2 trunk segments) of 18 lab rats. Rats were skinned, dried and assigned to 108 replicate tanks (~5x5x1"), each containing ten 1st instar skin beetle larvae (*D. maculatus*). Larvae were photographed weekly and measured (mm) using Image J. Emerging adults were weighed (g) and removed from tubbies as found. As expected, body region affected growth rate (ANOVA; p<0.0001 for both weeks), with the anterior trunk producing the largest larvae. Growth during weeks 1 and 2 showed dramatic effects (ANOVA; p<0.0112 week 1, p<0.0385 week 2), with the highest ketamine dose in combination with xylazine produced the largest larvae over both weeks. While increasingly larger doses of ketamine produced larger larvae, xylazine may buffer its effects, as combination treatments of lower ketamine dosages did not significantly differ from control groups. These results suggest that forensic investigations using beetles to determine PMI require understanding the fat content of the meat and the drug combination/dose present in the body.

P2-93 HERNANDEZ , E.*; VáSQUEZ, O./A.; TORUCCO, A.; RAHMAN, MD./S.; University of Texas Rio Grande Valley; *eleazar.hernandez02@utrgv.edu*

Annual and Lunar Reproductive Rhythms of the Atlantic Sea Urchin in the Southern Gulf of Mexico

The Atlantic sea urchin, *Arbacia punctulata*, is a unique invertebrate and a primeval species of the phylum Echinodermata. Natural phenomena such as water temperature and moonlight act as external cues that stimulate the reproductive activity of aquatic organisms. In order to acquire a better understanding of the correlation between gonadal maturity, lunar reproductive rhythm and spawning season in the economically and environmentally important marine species, the focused objective of our study was to determine the annual and lunar reproductive rhythms of the Atlantic sea urchin in the southern waters of Texas in the Gulf of Mexico. Sea urchins were collected monthly from July 2016 to June 2017 and sampled weekly in accordance with the lunar cycle from May to July in 2017 in South Padre Island, Texas. The gonadosomatic index (GSI, a biological indicator of isometric growth in gonads) of each sea urchin was calculated as the percentage of gonad weight/total body weight measurements. Gonadal tissues were sectioned and stained with hematoxylin-eosin. Subsequent histological examination of ovaries and testes was performed: maturity levels and spawning phases were determined quantitatively by calculating the percentage of oocytes (immature egg) and ova (mature egg) for each female and the production of sperm for each male. Collectively, our histological analysis suggests that Atlantic sea urchin spawns synchronously according to the lunar cycle and could spawn several times for the following summer months in the southern Gulf of Mexico.

P1-63 HERNANDEZ, AV*; COHEN, KE; GIBB, AC; PORTER, ME; Florida Atlantic Univ., Univ. of Washington, Northern Arizona Univ.; *ahernandez2013@fau.edu*

Why So Cirrihous? Functional morphology of cirri in Cottoidea species

Some teleosts species have elongate and projecting structures on their heads that have been called barbels or cirri. Barbels have been well studied and are described as sensory structures in Siluriformes and Acipenseriformes. Cirri functions are characterized differently among teleost fish groups. In the current study, we investigate the functional morphology of the cirri on five species within Cottoidae (Blepsias cirrhousis, Clinocottus globiceps, Jordania zonope, Nautichthys oculofasciatus, Oligocottus rimensis). Cirri in these species represent morphological diversity, ranging from few to numerous and simple to ornate. This study addresses the following questions: (1) What are the morphological and histological components of cirri? and (2) What functions do cirri serve? Examination of cleared and stained specimens suggest that the cirri in three of these five species are supported by cartilaginous rods. Using scanning electron microscopy, we observed structures on the cirri and nasal pores of these species with morphology similar to that of the taste buds documented in the barbles of Siluriformes and Acipenseriformes. Interestingly, taste bud morphology varied among the five species studied here and warrants further histological investigation. Differences in structure and function of cirri found across the five species may be due to variable ecology and habitat — where they may serve lesser or more significant roles. Because cirri are often used to describe and differentiate among species in Cottoidae as well as in other groups with similar structures, elucidating the functional morphology of cirri in this group will help determine their value as characteristics for morphometric and systematic studies.

S8-11 HERNANDEZ, LP*; COHEN, KE; The George Washington University, Univerisity of Washington; *phernand@gwu.edu*

Multifunctional structures and multistructural functions: How these phenomena characterize the evolution of morphological novelties within Cypriniformes

While functional morphologists have long studied the evolution of suites of trophic structures, the origin and evolution of morphological novelties has received less attention. One difficulty regarding the incorporation of the origin of anatomical novelties into evolutionary theory is that novelties may originate in piecemeal fashion rendering them more difficult to study. Alternatively, there may be times when complex structures originate all at once. When such complex novelties first originate they must become incorporated into an existing system to be rendered fully functional. Thus, morphological integration is key at the outset of acquisition of morphological novelties. However, given enough evolutionary time such linkages may be broken, allowing for a division of labor that is facilitated by subsequent decoupling of previously integrated structures. Cypriniformes is a diverse group of freshwater fishes characterized by several trophic novelties that include: kinethmoid-mediated premaxillary protrusion, a muscular palatal organ, hypertrophied lower pharyngeal jaws that masticate against the base of the neurocranium, and an epibranchial organ used to aggregate small food particles. Here, we use the wealth of such novelties in different cypriniform fishes to illustrate cases in which trophic novelties require other previously established structures to function appropriately (multistructural functions), such as the co-option of respiratory muscles for the purposes of food aggregation within the epibranchial organ. We will also discuss individual structural novelties that have subsequently become decoupled to take on different functions (multifunctional structures).

P2-194 HERNANDEZ, J*; HUCUL, CE; BELDEN, LK; MOORE, IT; Virginia Tech; *jess228@vt.edu*

The influence of extra-pair paternity on the cloacal microbiome of a free-living bird

Socially monogamous females that engage in extra-pair copulations face potential fitness trade-offs including, but not limited to, good genes and increased genetic diversity in offspring, but also loss of paternal care and increased harassment by their social partner. Sexually transmitted pathogenic microbes have been suggested to be a cost of extra-pair copulations for female birds for nearly five decades, but this hypothesis has not yet been adequately tested. To determine how extra-pair copulations are related to the composition of the cloacal microbiome, we performed an observational study of free-living female tree swallows (*Tachycineta bicolor*) during the breeding season in southwestern Virginia. Tree swallows are a socially monogamous box-nesting species that exhibit high rates of extra-pair activity that vary both within and between populations. First, we characterized the cloacal microbiome of females by collecting cloacal swabs and determining the taxonomic composition of cloacal bacteria using 16s rRNA gene amplicon sequencing. Then, we used nestling paternity as a conservative proxy to estimate the frequency of extra-pair copulations and to determine the minimum number of sexual partners per female. This study increases our understanding of how sexual activity, specifically extra-pair copulations, influences the cloacal microbial communities of wild birds. Additionally, this study broadens our understanding of the potential costs of common life-history tradeoffs faced by free-living animals.

P1-252.5 HERNANDEZ, A. M.*; RYAN, J. F.; Whitney Laboratory for Marine Bioscience, University of Florida; *ahernandez6@ufl.edu*

A comprehensive assessment of 6-state recoding in phylogenetics

Dayhoff, JTT, and LG matrices are 20-state amino acid replacement models used to score amino acid substitutions in phylogenetic analyses. Recently, recoding amino acid matrices into six groups based on substitution frequency in these models has been proposed as a solution to problems associated with substitution saturation and compositional heterogeneity in phylogenetic analyses. While these strategies have some appeal from a theoretical perspective, they have never been empirically tested. To test the performance of Dayhoff-6 and S&R-6 recoding, we used simulations to determine if recoding is truly appropriate to address saturation and compositional heterogeneity. If recoding is appropriate, the expectation is that as saturation or compositional heterogeneity levels increase, recoded matrices should outperform non-recoded datasets. On two separate trees that include a wide range of animals and a few closely related outgroups, we simulate 1,000 datasets of 1,000 amino-acids under the Dayhoff and JTT models and increase branch lengths from 1 to 20 in increments of 1. We show that this increase in branch lengths corresponds with saturation. For each dataset, we reconstruct trees using both recoded and non-recoded models. In both cases, trees produced under recoding strategies were consistently suboptimal to those produced under non-recoded matrices when comparing Robinson-Foulds distances. Similar simulations to test compositional heterogeneity are ongoing. Our preliminary results suggest that these flavors of recoding do not improve the accuracy of phylogenetic reconstruction and that results based on these schemes should be reevaluated.

99-3 HERNDON, CJ*; FENTON, FH; Georgia Institute of Technology; *co.herndon@gmail.com*

Tell-Tale Hearts and the Descent into Cardiac Chaos

Proper contraction of cardiac muscle relies on the coordinated propagation of transmembrane voltage, and disturbances of this propagation can result in deadly cardiac arrhythmias such as fibrillation, the manifestation of chaos in the heart. Even in healthy tissue, high heart rates can drive the system to a dynamical instability known as alternans, a period doubling bifurcation in action potential duration (APD) which is strongly correlated with the onset of fibrillation and sudden cardiac death. A functional relationship between the APD and preceding diastolic interval (DI) known as the restitution hypothesis aims to predict the onset of alternans. Much theoretical effort based on the restitution hypothesis has aimed to suppress the onset of alternans through cardiac stimulation at a constant DI with very positive results; however, few experiments have addressed these predictions. In this talk, I will discuss comparative cardiac dynamics in the hearts of species including rabbit, dog, cat, pig, frog, zebrafish, snake, lizard, and alligator through the use of microelectrode recordings and high spatiotemporal resolution optical mapping of fluorescent voltage and calcium signals across the surfaces of hearts. Furthermore, I will discuss my closed-loop control system for performing constant DI stimulation and the highly unexpected results.

38-4 HERREL, A*; ORPEL, J; PADILLA, P; COURANT, J; REBELO, R; UMR719 CNRS/MNHN, Faculdade de Ciências da Universidade de Lisboa; *anthony.herrel@mnhn.fr*

Do invasive populations of Xenopus laevis living in different environments differ in morphology?

Xenopus laevis is generally considered as one of the worst invasive amphibians world-wide having colonized many countries on at least four continents and with new invasions being reported on a regular basis. Despite the negative impact this species has on native amphibians and freshwater invertebrates, the invasive populations provide an excellent model system to explore whether and how these animals have adapted to novel ecological conditions. Here we compare external morphology, organ size and limb muscle mass for two invasive populations characterized by different habitats. Whereas in France this species has invaded ponds and stagnant water bodies, in Portugal the species is present in fast flowing streams. Our results show significant differences with animals in France relatively wider heads relative to their size while Portugese individuals which have relatively longer heads. Moreover, Portugese frogs had a longer tibia and longer and wider ilia, larger lungs and a heavier intestinal tract. French frogs had longer femora, longer fingers and toes and males specifically had larger kidneys. In terms of muscles only the pectineus was better developed in the Portugese frogs whereas the adductor longus, the quadratus femoris, the semimembranosus, the semitendinosus and the tibialis anticus are better developed in frogs from the French population. These results show that frogs have adapted to the specific constraints of the different habitats.

134-6 HERRERA, MJ*; GERMAN, DP; Univ. of California, Irvine; *mjherre1@uci.edu*

Digestive performance and microbiome changes in response to dietary shifts in closely-related prickleback fishes (Family Stichaeidae) with different natural diets.

Investigating closely related, sympatric, animals with different natural diets will further our understanding of how changes in diet affect an animal's intestinal microbial community and gut function. We examined four closely-related prickleback fishes that naturally vary in diet: *Xiphister mucosus* (herbivore), *X. atropurpureus* (omnivore), *Phytichthys chirus* (omnivore), and *Anoplarchus purpurescens* (carnivore). We are comparing enteric microbial diversity amongst wild-caught individuals of the four species, and among the wild-caught individuals and those fed different diets in the laboratory within a species. Food and feces collected throughout the feeding experiment are being used to calculate organic matter digestibility, and we are using gas chromatography to measure the concentrations of short chain fatty acids (SCFA), which are the products of microbial fermentation, in the fishes' distal intestines. We expect some core taxa to not change in abundance in the face of dietary changes, whereas others will show dietary-related changes in abundance. As none of these fish species are known to rely on hindgut fermentation, we don't expect SCFA concentrations to vary widely among the species or feeding treatments. We have found clear dietary effects on the microbiome. Carnivores have higher Bacteroidetes:Firmucutes ratios compared to omnivores and herbivores. Analysis of digestibility and the abundance of the various microbial taxa are underway. Our results will contribute to the larger goal of understanding how intestinal microbiomes respond to dietary shifts in animals with different natural diets, but with phylogenetic control of the studied organisms.

P1-181 HERRMANN, M/A*; ROMERO-DIAZ, C; CAMPOS, S/M; MITER, G/A; WILLIAMS, D/R; SOINI, H/A; NOVOTNY , M/V; HEWS, D/K; MARTINS , E/P; School of Life Sciences, Arizona State University, Tempe AZ, USA, Department of Biology and Center for the Integrative Study of Animal Behavior, Indiana University, Bloomington IN, USA, Department of Chemistry, Indiana University Bloomington, IN, USA, Institute for Pheromone Research and Department of Chemistry, Indiana University Bloomington, IN, USA, Institute for Pheromone Research and Department of Chemistry, Indiana University Bloomington, IN, USA, Department of Biology, Indiana State University, Terre Haute IN, USA; *morgan.herrmann@asu.edu*

The Effects of Chemical Signal Content in Social Communication of Lizards

Odor signals are involved in feeding, territorial, social and reproductive behavior of animals. Most chemical scents are complex blends of multiple compounds, yet varying proportions of different chemical combinations may lead to different levels of signal response. We conducted a series of chemical playbacks, in a controlled environment, with lizards of the genus *Sceloporus*, to assess behavioral responses to two volatile heterocyclic compounds, identified from femoral pore secretions and a demonstrated role in communication in other taxa. These compounds were presented alone or in combination with each other and in different proportions. We found evidence supporting the hypothesis that varying either the number or the proportion of the compounds significantly alters individual responses to chemical scents. Interestingly, the relationship between the two compounds was interactive rather than purely additive. These results provide deeper insight into the effect of chemical signal content in communication and behavior.

S4-11 HESSE, L.*; MASSELTER, T.; LEUPOLD, J.; BUNK, K.; SPECK, T.; Plant Biomechanics Group and FIT, University of Freiburg, Medical Physics, Medical Center, University of Freiburg; *linnea.hesse@biologie.uni-freiburg.de*

Biomechanics and development of plant branch-stem-attachments as inspiration for optimized fiber-reinforced anchors

Branched biological fiber-composite lightweight designs have evolved in diverse plant groups revealing various shapes and inner tissue structuring. The existing type of branches and branching architectures are the result of structural and biomechanical optimizations in the course of evolution. Branches are designed to withstand static (e.g. net weight) and dynamic (e.g. wind) loads while having a benign fracture behavior. Thus, branched plants are suitable concept generators for the biomimetic optimization of branched technical fiber-reinforced structures. However, a deepened understanding of the form-structure-function principles of plant branches require for novel methodological approaches that allow non-invasive and non-destructive repetitive 3D to 4D in vivo imaging of plant tissues. In this study, we used traditional and modern 3D to 4D imaging methods to reveal the functional morphology, biomechanics and development of the branch-stem-junction in plants. A novel methodological approach based on magnetic resonance imaging allowed for in vivo analysis of a load-adapted tissue placement and its development in dragon tree branches. In addition, we shortly demonstrate the potential of functional plant MRI for analyzing further, up to now, unsolved scientific questions concerning e.g. plant self-repair or movement.

P1-111 HEUERMANN, T M*; CURRY, R L; Villanova University; *theuerma@villanova.edu*

Inter- and intra-specific variance in boldness behavior of hybridizing Black-capped and Carolina chickadees

Animal personality, behavior consistent within but variable among individuals, influences evolution in both predictable and changing environments. Our research program focuses on interactions between black-capped and Carolina chickadees in southeastern Pennsylvania where their ranges overlap in a hybrid zone. As climate change drives the hybrid zone northward, understanding the species' response mechanisms to change becomes increasingly important. In this study, we investigated boldness behavior in pure and mixed populations of Black-capped and Carolina chickadees. To measure boldness response, we used a motorized woodpecker decoy as a simulated threat at active nests. Most assays elicited a pair response, while video recordings provided individual-level behavioral measures. Preliminary analysis indicates that in terms of latency to make the first ‘chick a dee' alarm call and total call rate, pairs in all populations behaved similarly; however, black-capped chickadees gave fewer dee notes (less intense response) than chickadees from Carolina or hybrid-zone populations. A secondary focus of this study is how variation in a personality-related gene, DRD4, contributes to these differences in boldness response. Prior work in our lab indicates that a single nucleotide polymorphism in DRD4 exists in different frequencies between Carolina and Black-capped populations. Work in progress aims to determine whether a relationship exists between boldness response and DRD4 genotype.

P3-98 HEWINS, B; RIDEOUT, A; HARDING, W; MACDONALD, E; FERGUSON, L; GIBSON, G*; Acadia University; *glenys.gibson@acadiau.ca*

Effects of Environmentally-Relevant Levels of Microplastics on Tissue Structure in Mytilus edulis (Blue Mussels)

A major environmental stressor facing marine organisms is the near-ubiquitous glut of microplastics in ocean ecosystems. We investigated the effects of microplastics on the histology of the bivalve mollusc *Mytilus edulis*, filter feeders that are highly abundant in coastal ecosystems. Our objective was to determine if microplastics are taken up into tissues at high risk of exposure (e.g., gills, hepatopancreas) and to use histochemistry to look for tissue-level effects. We exposed mussels to polystyrene particles (5 micrometer diameter) at a low concentration that is typical of water samples of the mid-Atlantic Ocean (1-2 particles/ m3) and at a higher concentration characteristic of some coastal areas (100x low). Controls included field-sampled mussels and mussels cultured in the lab but without polystyrene exposure. After a six-week exposure, we compared the histology of the gills and hepatopancreas in paraffin section using histochemistry. We examined potential changes in basic tissue structure (Hematoxylin and Eosin, Gomori trichrome), mucin production and distribution of hemocytes (periodic-acid Schiff-Alcian Blue), as well as classic indicators of immune responses including lipofuscin production and melanisation (Nile Blue). Preliminary results suggest that polystyrene exposure, even at these low concentrations, was associated with several stress-related responses in both organ systems.

134-8 HEYDUK, K*; RAY, JN; CUMMINGS, A; LEEBENS-MACK, J; Yale University, University of Georgia; *karolina.heyduk@yale.edu*

Variation in the ability to use CAM in a C3-CAM hybrid Yucca

Photosynthetic organisms are the foundation of ecosystems across the globe, yet the photosynthetic pathway is highly susceptible to stress via water limitation. Plants that live in desert or in other water-limited habitats can close stomata to preserve water, but frequent or prolonged stomatal closure prevents CO_2 from entering the cells and will eventually starve plants of carbon. To circumvent this problem, multiple lineages of flowering plants have evolved a modified form of photosynthesis known as Crassulacean acid metabolism (CAM). CAM plants, which comprise 7% of all flowering plants and have evolved at least 35 independent times, open their stomata at night to acquire CO_2 when temperatures are lower and less water is lost to the atmosphere. CAM plants store the CO_2 acquired at night as malic acid in their cells, then during the day close stomata and decarboxylate the malic acid. The result is high concentrations of CO_2 in the cells for efficient photosynthesis, all while minimizing water loss. CAM is remarkable, in that its evolution requires plants to modify a central metabolic pathway without significant losses in fitness. To understand the physiological and genomic landscape that may have preceded the evolution of CAM, we investigated the drought response and ability to upregulate CAM in the C_3-CAM hybrid *Yucca gloriosa*. Using a combination of gas exchange measurements and time course RNAseq, we show variation in how genotypes respond to drought stress, how much they can rely on the CAM phenotype, and significant variation in gene expression, including in circadian clock regulatory pathways. While there is variation among genotypes, the variation is limited in its extremes, suggesting a small phenotypic and genotypic space where the fitness of the hybrid remains sufficiently high for survival.

S12-5 HIGHAM, Timothy E.*; RUSSELL, Anthony P.; NIEWIAROWSKI, Peter N.; WRIGHT, Amber N.; SPECK, Thomas; Univ. of California, Riverside, Univ. of Calgary, Univ. of Akron, Univ. of Hawaii, Univ. of Freiburg; *thigham@ucr.edu*
Adhering to nature: the importance of incorporating ecologically relevant information in the study of gecko adhesion
The study of gecko adhesion is necessarily interdisciplinary due to the hierarchical nature of the system and the complexity of interactions between animals and their habitats. In nature, Geckos move on a wide range of surfaces including soft sand dunes, smooth trees, and rough rocks, but much of the research over the past two decades has focused on the interaction between geckos and artificial surfaces. The complex interactions between geckos and their natural habitats can likely reveal aspects of the adhesive system that can be applied to biomimetic research, such as the factors that facilitate movement on surfaces with specific microtopography. Additionally, contrasting suites of constraints and topographies are found on rocks and plants, likely driving differences in locomotion and morphology. Our overarching goals are to bring to light several aspects of ecology that are important for gecko-habitat interactions, and to propose a framework for how these interactions can inspire material scientists and functional ecologists. We address the following key questions: 1) What ecological factors drive adhesive performance? 2) How do geckos select the surfaces on which they move in nature? 3) How might geckos and plants co-evolve to facilitate mutualistic relationships? 4) How can ecological studies inform material science research? Recent advances in surface replication techniques that eliminate confounding factors among surface types facilitate the ability to address some of these questions. Using replicates, we determine the functional consequences of ecologically relevant surface features. Finally, we pinpoint gaps in our understanding and identify key initiatives that should be adopted as we move forward.

S8-9 HIGHAM, Timothy E.*; SCHMITZ, Lars; CLARK, Rulon W.; Univ. of California, Riverside, Claremont McKenna, Scripps, and Pitzer Colleges, San Diego State Univ.; *thigham@ucr.edu*
Dynamic functional Integration in organismal biology: Integrating motor and sensory systems during predator-prey interactions
Phenotypic integration is a major theme in evolutionary biology, focusing on the complex patterns of covariation among morphological structures, physiological traits, systems, or behaviors of an organism. In the context of biomechanical integration, morphology and motion (driven by motor systems) are often the center of focus. When sensorimotor integration is investigated, it is often limited to the neuromuscular control of locomotion. Among non-human animals, however, locomotion and feeding are often dependent on a variety of sensory modalities, such as visual, mechanical and/or thermal cues. For some species, multisensory integration is common, and may also provide a redundancy that becomes important when one or more sensory modality changes or is disrupted. Utilizing different sensory cues may also alter the patterns of motor integration (e.g. locomotion and feeding), thereby altering the performance outcome. Using multiple animal systems (fishes, geckos, and snakes), we explore the links between integrated suites of traits and performance outcomes. Specifically, we address the hypothesis that rich sensory input enhances the ability of animals to integrate different motor systems during tasks. If this leads to greater success/performance, then this has likely driven the evolution of biomechanical traits. If sensory input is a constraint, then animals can alter their strategies in the face of temporal shifts in sensory environments, as is likely common for every animal, or limit a specific behavior to a time when the level of sensory input is adequate for the successful execution of important tasks. Finally, we develop a framework for assessing the integrated phenotype in the context of the sensory environment.

34-7 HIGHTOWER, BEN*; INGERSOLL, RIVERS; SHORR, DANIEL; CHIN, DIANA; LENTINK, DAVID; HIGHTOWER, Ben; Stanford University; *bhightow@stanford.edu*
How Hummingbirds Reorient Forces During Maneuvering Flight
Hummingbirds are among the most agile of birds, and even have the ability to hover in flight. While their flight kinematics have been studied extensively before, their aerodynamic forces have primarily been studied using indirect methods like inverse dynamics and particle image velocimetry, which are insufficient to capture the full weight support of the bird. Here we present *in vivo* force recordings of maneuvering Anna's hummingbirds feeding from a moving flower using a novel 3D aerodynamic force platform. The pressure field generated by the maneuvering bird travels to the boundaries of the flight arena, and the six instrumented plates mechanically integrate the resulting pressure and shear distribution at a high sample rate that records wingbeat-resolved forces. With these data, we can determine the tracking effectiveness of hummingbirds as well as the control methods they employ. Unraveling how hummingbirds manipulate aerodynamic forces with their wings to maneuver has profound applications to the study of other flying animals and the development of more maneuverable aerial robots.

S6-7 HILL, G. E.; HILL, Geoffrey; Auburn University; *ghill@auburn.edu*
Speciation and Sexual Selection as Processes to Maintain Mitonuclear Coadapation
Eukaryotic performance hinges on the coordinated function of the products of the nuclear and mitochondrial genomes in achieving oxidative phosphorylation. Because two genomes are involved, function is maintained only through perpetual selection for mitonuclear coadaptation. I propose that these fundamental features of the genomic architecture of eukaryotes results in both pre- and post-zygotic sorting for coadapted mitonuclear genotypes leading to both speciation and sexual selection. Mitonuclear coevolution in isolated populations leads to speciation because population-specific mitonuclear coadaptations create between-population mitonuclear incompatibilities and hence barriers to gene flow between populations. In addition, selection for adaptive divergence of products of mitochondrial genes, particularly in response to climate or altitude, can lead to rapid fixation of novel mitochondrial genotypes between populations and consequently to disruption in gene flow between populations as the initiating step in animal speciation. Selection for pre-zygotic sorting of mitochondrial and nuclear genotypes for functional compatibility is also proposed to lead to the evolution of ornaments. By this model, the defining characteristic of a metazoan species is a coadapted mitonuclear genotype that is incompatible with the coadapted mitochondrial and nuclear genotype of any other population.

40-3 HILL, GM*; TRAGER, M; LUCKY, A; DANIELS, JC; University of Florida, Gainesville, US Forest Service, National Forests in Florida, Tallahassee; *ghill@flmnh.ufl.edu*
Uncovering the benefits of an ant-butterfly mutualism in the Florida Keys
Ants and many lycaenid butterflies have evolved a mutualistic relationship, where ants feed on carbohydrate-rich secretions from larvae and in return may provide protective or physiological benefits to the butterfly. The Miami blue butterfly (*Cyclargus thomasi bethunebakeri*) is a federally endangered butterfly found only in the Florida Keys and associates with several ant species. Female Miami blue butterflies have shown to benefit physiologically from increased ant tending by carpenter ants (*Camponotus floridanus*). However, the primary advantage of ant association for lycaenid larvae is typically defense against natural enemies. We experimentally assessed the protective benefits carpenter ants may provide to Miami blue larvae against common insect predators. We also evaluated predation rates on various Miami blue life stages from two invasive ants: *Pseudomyrmex gracilis* and *Solenopsis invicta*. Interactions and behaviors were categorized and assessed to determine how behavior benefits protection. A life table determined which life stage has the highest probability of being predated. Difference in survivorship life stages was significant: eggs and early instar larvae had a higher probability of being predated since these life stages are not tended as frequently. Mortality of Miami blue larvae was significantly higher in the absence of *C. floridanus*, suggesting that these tending ants can be effective in protecting later instar larvae against insect predators. These results are critical for successful organism reintroductions and conservation efforts for the Miami blue butterfly, especially during a critical time as species interactions are changing in this vulnerable habitat.

28-7 HILL, A*; HILL, M; HALL, C; SACRISTAN-SORIANO, O; RIESGO, A; CAMILLI, S; DELBEAU, M; DWAAH, H; Bates College, Univ. of Virginia, Univ. of Richmond, Natural History Museum, London; *ahill5@bates.edu*
Sponge:Algal symbioses and the molecular genetic pathways involved in host:symbiont associations
Symbioses between phototrophs and heterotrophs are common in many ecosystems, and mechanisms have evolved to ensure long-term and stable interactions for these intracellular symbioses. Factors that permit stability of the association, or enhance performance of one or the other partner, are often poorly understood. Both marine and freshwater sponges offer a number of unique opportunities to examine the pathways to persistence for phototrophic algal symbionts in heterotrophic host cells. The goal of this work is to elucidate genetic and cellular factors that contribute to tight integration of hosts and symbionts, while also exploring evidence of convergent evolution in partnerships involving distinct algal symbionts and heterotrophic hosts. We will discuss how we take advantage of unique properties of marine and freshwater sponge hosts (*Cliona varians* and *Ephydatia muelleri*) and their algal partners (*Symbiodinium* and *Chlorella*) to monitor and control the timing of symbiont reinfection. We sequenced transcriptomes and analyzed differential gene expression patterns observed in algal-free sponges and algal-free sponges exposed to bacteria, heat-killed algae, and live algae in both the marine and freshwater system. From these data, we identify genes and putative pathways involved in early symbiont acquisition and ask if some aspects of the regulation of these symbioses may be the product of convergent evolution. As well, we present preliminary data using pharmacological inhibitors to block identified gene/pathways to examine functional aspects of the host:symbiont association.

69-5 HILL, EH*; JARMAN, MJ; BUTLER, MA; University of Hawaii; *hille7@hawaii.edu*
Living the "High" Life: The Morphological, Kinematic, Ecological and Genetic Variation between Papuan Microhylid Frogs at Lower and Higher Elevations
Papua New Guinea is home to over 300 species of microhylid frogs. These species inhabit environments from coastal environments to to the Western Highlands Province that begins at an elevation of 1,677 meters. We explored adaptation to life at high elevation by comparing ecomorphology of frogs between low and high elevation communities. We collected morphology, performance, and ecology data from seven species in a high-elevation community at Rondon Ridge (Western Highlands Province) and compared ecomorphology with lower-elevation communities, all within a phylogenetic context. We analyzed hindlimb, forelimb, toepad morphology and jumping kinematics in relation to microhabitat use. We sequenced 2 mitochondrial and 3 nuclear genes (Cytb, BDNF, ND4, NCX-1 and SIA) and included these highlands species into a larger microhylid phylogeny. Comparison between microhylid assemblages at different elevations could bring to light functional adaptations for high elevation as well as illuminating the patterns of diversification in the lesser-known central Paupan region.

43-4 HITE, JL*; CRESSLER, CE; University of Nebraska-Lincoln; *jessicahite@gmail.com*
The evolutionary, epidemiological, and ecological consequences of parasite-mediated anorexia
Parasite-mediated anorexia is a ubiquitous, but poorly understood component of host-parasite interactions. These temporary but substantial reductions in food intake (range: 4-100%) limit exposure to parasites and alter within-host physiological processes that regulate parasite development, production, and survival, such as energy allocation, immune function, host-microbiota interactions, and gastrointestinal conditions. By altering the duration, severity, and spread of infection, anorexia could substantially alter ecological, evolutionary, and epidemiological dynamics. However, these higher-order implications are typically overlooked and remain poorly understood — even though medical (e.g., non-steroidal anti-inflammatory drugs, vaccines, targeted signaling pathways, calorie restriction) and husbandry practices (e.g., antibiotic and diets used for rapid growth, nutrient supplementation) often directly or indirectly alter host appetite and nutrient intake. We develop theory that helps elucidate why reduced food intake (anorexia) can enhance or diminish disease severity and illustrates that the population-level outcomes often contrast with the individual-level outcomes: treatments that increase the intake of high-quality nutrients (suppressing anorexia), can drive rapid individual-level recovery, but inadvertently increase infection prevalence and select for more virulent parasites. Such a theory-guided approach offers a tool to improve targeting host nutrition to manage disease in both human and livestock populations by revealing a means to predict how nutrient-driven feedbacks will affect both the host and parasite.

P3-83 HITT, LG*; BLANCHETTE, A; KHALIL, S; FINKELSTEIN, ME; RIBEIRO, RD; IVERSON, ENK; MCCLELLAND, SC; KARUBIAN, J; Tulane Univ, Univ of California, Santa Cruz, Royal Holloway Univ of London; *lhitt1@tulane.edu*

Effects of Lead Exposure on Reproductive Success and Extra-Pair Paternity in the Northern Mockingbird

Chronic, sublethal exposure to lead, a common urban contaminant, causes behavioral and physiological problems in humans living in cities, but little is known about the effects of lead exposure on urban wildlife. Our previous work on the northern mockingbird (*Mimus polyglottos*) in New Orleans suggests that birds in high-lead neighborhoods have higher concentrations of lead in their blood and feathers and are more aggressive. Here, we examine how the reproductive output and cuckoldry rates of mockingbirds may be impacted by lead exposure. On the one hand, more aggressive, high lead males may obtain higher quality territories and resources and mate guard more effectively, leading to high reproductive output and reduced cuckoldry rates within their nests. Conversely, high lead birds may experience reduced reproductive output via direct impacts of lead exposure on the survival of eggs and nestlings, and increased cuckoldry through infertility or excessive aggressive behavior. Our findings provide insights into how lead exposure may mediate fitness via tradeoffs between aggressive behavior, cuckoldry rates, and offspring survival.

P3-58 HITTLE, KA*; KWON, ES; COUGHLIN, DJ; Widener University, Chester, PA; *kahittle@widener.edu*

Climate Change and Anadromous Fish: How Does Thermal Acclimation Affect the Mechanics of Myotomal Muscle of Atlantic Salmon, Salmo salar?

Climate change is leading to rapid changes to ecosystems worldwide. In response to accelerated temperature shifts, to survive many species must acclimate to their shifting thermal environment. We were interested in how climate change will impact a commercially and recreationally important species of fish, Atlantic salmon (*Salmo salar*). Native to the North Atlantic, these anadromous fish live their first few years in small streams and rivers before migrating to the ocean where they grow to adult size. As climate change alters the thermal environment of their natal streams, we asked how their muscle function will be altered by extended exposure to both warm and cold temperatures. We performed a thermal acclimation study of salmon swimming performance (U_{crit}) and muscle function for groups of fish acclimated to 4, 12 and 20°. After swimming performance experiments, muscle mechanics of both fast-twitch or white and slow-twitch or red myotomal muscle bundles were investigated across a range of experimental temperatures. U_{crit} did not vary with thermal acclimation when tested at a common experimental temperature (10°C). White muscle displayed modest shifts in function with thermal acclimation, while red muscle showed very little variation. Typically, the fastest contractile properties were observed in the muscle from the 12°C acclimation group. Fish from both coldest and warmest acclimation groups displayed slower kinetics when tests across a range of common experimental temperatures. Overall, Atlantic salmon appear to have limited ability to acclimate across a range of physiologically relevant temperatures, suggesting that climate change will pose of challenge to this already threatened species.

132-2 HOCH, JM*; SPADAFORE, S; CABANELAS, A; Nova Southeastern University; *jhoch@nova.edu*

Fish Personality Variation Affects Migration and Dispersal in the Dynamic Wetlands of the Everglades

The Everglades ecosystem is characterized by seasonal rains that expand and reduce habitat available for aquatic organisms. Small fish like Eastern Mosquitofish (*Gambusia holbrooki*) move in and out of temporary wetlands each year. Previous field studies have indicated a cyclic change in activity and directionality for some fishes moving across the landscape and that movement rates vary among species. Laboratory experiments were performed to test the hypotheses that the personality, boldness, risk aversion, exploration efficiency and other behaviors related to migration vary among fishes from locations with different hydrology (the Everglades versus Lake Okeechobee) and during different periods of the water year. We found that Eastern Mosquitofish were bolder and were superior explorers of unknown environments during periods of changing water levels. These fish are one of the main resources for wading birds. We performed experiments to determine whether cues from these predatory birds affect how willing the fish are to take on risk of migration, how bold they are and other aspects of their behavior in anticipation of migration. We found that the presence of chemical cues (bird feces) and visual cues (an egret model) increased boldness and the likelihood of exploration by the fish, perhaps indicating that predator risk is one cue used by the fish start migrating. We confirm prior studies showing seasonally changing activity levels by migrating fishes and demonstrate that seasonal changes to personality are partially responsible.

122-1 HODGE, JR*; SANTINI, F; WAINWRIGHT, PC; Univ. of California, Davis; *jhodge@ucdavis.edu*

One Fish, Two Fish, Reef Fish, Blue Fish: Dichromatism in Fishes as an Adaptation to Life on Coral Reefs

Naturalists have long sought to explain the drivers of conspicuous colour evolution. Wrasses and parrotfishes display conspicuous coloration during the terminal phase, which transitions from a duller initial phase with growth. The degree of colour difference between phases, dichromatism, ranges from extreme to none, and appears more pronounced in species that live on coral reefs. Here traits that are thought to promote the evolution of dichromatism via sexual selection, including protogynous sex change and polygynous mating, are purportedly more common. Support for this hypothesis is limited to qualitative assessments and the claims have not been subject to rigorous comparative analysis incorporating evolutionary history. Here we use phylogenetic comparative methods to quantify the interaction and relative effects of selective pressures driving the evolution of dichromatism. We show that wrasses and parrotfishes exclusive to coral reefs are the most dichromatic, but surprisingly, this effect is not influenced by sexual ontogeny or mating system. While selective pressures acting on both initial and terminal phases might affect the magnitude of dichromatism, they vary with habitat only among terminal phase fishes that are more likely to display blue colours on coral reefs. Habitat-specific conditions including clear water may underlie the adaptation of specialized visual signals and perception; however, we find that depth is not a contributing factor. Fishes on coral reefs are more likely to display dichromatism on permanently-visible body regions, suggesting the structural refuge of coral habitats may mitigate any increased risk of predation to conspicuously coloured fishes. Our results show that environmental conditions ultimately shape the selective forces underlying the evolution of pronounced dichromatism.

85-7 HODINKA, BL*; ASHLEY, NT; Western Kentucky Univ., Bowling Green; *brett.hodinka420@topper.wku.edu*

Effect of sleep loss on cognitive function and baseline plasma corticosterone levels in an arctic-breeding songbird, the Lapland longspur (Calcarius lapponicus)

Sleep is a fundamental and essential component of vertebrate life, although its exact function remains unknown. Animals that are deprived of sleep typically show reduced neurobiological performance, health, and in some cases, survival. However, a number of animals exhibit adaptations that permit them to carry out normal activities even when sleep is restricted or deprived. Lapland longspurs (*Calcarius lapponicus*), arctic-breeding passerine birds, exhibit around-the-clock activity during their short breeding season, with an inactive period of only 3-4 h/day (71 °N). Whether these birds suffer behavioral and physiological costs associated with sleep loss (SL) is unknown. To assess the effects of SL, wild-caught male longspurs were placed in captivity on long days (16L:8D) and trained for 2 months using a battery of memory tests, including color association, spatial recognition, and color reversal to assess executive function. Birds were then subjected to automated sleep fragmentation cages that interrupt sleep every 2 min (30 arousals/h) for 12 h or control conditions. The criterion for success on each test was marked by completing the operant task correctly within 10 min. After SL (or control) treatment, birds were bled from the alar wing vein to measure plasma corticosterone levels. Preliminary data suggest that SL individuals performed equally, if not better than non-SL individuals, on cognitive tests. These results indicate that this arctic-adapted species may have evolved behavioral and/or physiological adaptations to withstand the costs associated with SL.

P3-78 HOEKSTRA, LH*; JUDSON, JM; JANZEN, FJ; BRONIKOWSKI, AM; Iowa State University; *lhoek@iastate.edu*

Quantitative Genetics of Life History in a Population of Long-Lived Reptiles

Comparative studies of the evolutionary genetics of complex traits remain limited by sparse taxonomic sampling of natural populations, particularly for life-history traits, such as lifespan and lifetime reproductive fitness, that require sampling the full life course of individuals. Not surprisingly, most existing estimates of the inheritance of such life-history traits come from model organisms in laboratory settings (e.g., flies, mice) or from species of particular interest to humans (e.g., humans, horses, dogs, birds). However, recent advancements in genomic sequencing and new methods for inferring wild pedigrees allow the development of non-traditional model systems. The Western painted turtle, *Chrysemys picta*, is an excellent candidate for studying the quantitative genetics and life-history evolution of a long-lived ectothermic vertebrate. As with many turtles, painted turtles lack sex chromosomes, yet still exhibit a suite of sexually-dimorphic traits throughout their lifetime. Extensive mark-recapture and census efforts of a wild population of painted turtles along the Mississippi River in Thomson, Illinois have provided sound estimates of demographic parameters, including sex ratio, vital rates, and heritability of nesting behavior. We leveraged 25 years of tissue samples collected during this longitudinal field study to genotype a large fraction of the population (N=900). We used the resulting genome-wide SNP panel to associate phenotypic variation in life-history traits (e.g., size-at-maturity, reproductive effort, lifespan) with population-genetic variation, addressing key questions about the sex-specific heritability of life history.

90-2 HOFFMAN, AJ*; FINGER , JW; WADA, H; Auburn University; *ajh0077@auburn.edu*

Early Stress Priming and Maintenance of a Sexually-selected Trait and Oxidative Status

Developmental stressors have been classically seen as maladaptive. However, at a certain magnitude and duration, such stressors can result in adaptive phenotypic adjustments, allowing the organism to maintain fitness in an otherwise unfavorable future environment. Without such adjustments, animals face a trade-off between self-maintenance and reproduction. This resource trade-off may come at the expense of sexually selected traits, which can serve as an honest indicator of condition. These traits are common in birds, with red ornaments getting their pigment through carotenoids, which are also thought by some to play a part in oxidative physiology. In zebra finches (*Taeniopygia guttata*), females prefer males with redder beaks; and redder beaks are also positively correlated with immune function, survival, and reproductive success. We tested the hypothesis that male zebra finches exposed to a prolonged mild heat stressor early in life will be better able to cope with a high heat stressor as adults, allowing them to maintain a sexually selected trait and oxidative status. To do this, we exposed juvenile male zebra finches to a prolonged mild heat stress (38° C) or control (22° C) temperature over a period of 28 days. As adults, the birds were then exposed to either a high heat stressor (42° C) or control temperature for 3 consecutive days. Bill color was measured before and after the adult treatment using digital photographs, from which values for hue, saturation, and brightness were quantified. Following the final treatment bout, birds were euthanized and organs removed. Using Western blots we quantified antioxidant enzyme levels [superoxide dismutase (SOD-1 and SOD-2)] and oxidative damage (4-hydroxynonenal). The results will be discussed in relation to mechanisms of adaptive plasticity and resource trade-offs.

P3-45 HOFFMANN, KA*; CHANG, E; LENTINK, D; Stanford University; *khffmnn@stanford.edu*

Towards Highly Maneuverable and Efficient Avian-Inspired Bio-Hybrid Flying Robots with Morphing Wings

The mystery of understanding how birds fly also has significant benefits in a major area of micro air vehicle (MAV) and general unmanned aerial vehicle research: improving maneuverability and efficiency to allow for flying highly dynamic, longer missions. A bird's ability to morph its wings enables highly dynamic and efficient flight. This results in greatly improved performance compared to fixed wing aircraft of comparable size and weight, which are optimized for limited sequences of flight. We developed a feathered bio-hybrid flying robot to better understand how birds use their feathers to control flight. Closely mimicking pigeon wings enables us to understand the possible maneuvers enabled through wing morphing, and how to perform them in a repeatable, controlled manner. We adapt well understood equations of motion from traditional fixed wing aircraft to simulate our morphing wing bio-hybrid robot. By building our understanding of the maneuvers possible with morphing wings, we will be able to use this information to fly difficult missions autonomously, for example through a set of defined waypoints or to track another flying object using morphing for primary flight control. Better understanding the dynamics of the bio-hybrid wing are also essential for the development of disturbance rejection, such as stabilizing in gusty turbulent conditions. All of these developments lead towards a fully autonomous bio-hybrid aerial robotic platform. Finally, the robot and mathematical models offer deeper insight into how birds may control their flight.

P3-19 HOFFMANN, SL; PORTER, ME*; Florida Atlantic University, 1992; *me.porter@fau.edu*

Three-dimensional fin kinematics of submerged walking in the epaulette shark

Epaulette sharks (Hemiscyllium ocellatum) use tetrapod-like walking with a variety of gaits that involve sequential fin movements to advance the animal forward. During walking, the fins rotate about the proximal insertion and undergo conformational changes to contact the substrate. The goal of this study was to quantify the three-dimensional (3D) kinematics of the pelvic and pectoral fins during steady walking. Three juvenile epaulette sharks were outfitted with markers along the fins and body and filmed submerged walking in a 50 L aquarium. We calibrated two GoPro Hero 5 Black cameras with overlapping views for 3D analysis and tracked marker movement in XMALab. We placed four markers at the proximal pectoral fin insertion and four markers along the pectoral girdle that were used to model pseudo-rigid bodies to quantify fin rotation in relation to the body axis using Autodesk Maya 2017. We used additional markers distributed throughout the distal and trailing fin edge to quantify the conformational changes of the fins. Fin rotation and conformation were compared to the velocity, duty factor, and stride frequency of the trials to determine the role of fins in walking performance. Our data show that both pelvic and pectoral fins rotate in three axes during walking, and that both fins undergo substantial conformational changes during walking. The fin rotation quantified in this study greatly exceeds that observed during yaw maneuvering in other shark species. The pelvic and pectoral fins and girdles, and associate musculature, of epaulette sharks are previously described as highly specialized to facilitate walking along the substrate. We suggest that this increased musculature and high degree fin rotation and flexibility allows this species a greater degree of control needed for more complex walking movements.

35-7 HOLDEN, KG*; GANGLOFF, EJ; BRONIKOWSKI, AM; Iowa State University, Station d'Ecologie Théorique et Expérimentale du CNRS; *pettinkg@iastate.edu*

Insulin and the Stress Response of Garter Snakes Exposed to Temperature Extremes

As global climate patterns change, quantifying thermal reaction norms for metabolic and hormonal function is increasingly important. In particular, characterizing the physiological response to both heat stress and prolonged cold exposure in ectotherms is essential for understanding the maintenance of long-term energy balance. Glucocorticoids, such as corticosterone, are often assayed to evaluate the physiological response to stress by the hypothalamic-pituitary-interrenal (HPI) axis in reptiles. However, other biomarkers, such as circulating levels of blood glucose and insulin, provide more specific information on energy balance by which we can quantify organismal responses to potentially stressful conditions, including thermal extremes. Under homeostatic conditions, insulin generally modulates glucose uptake into tissues. However, in mammals, there is evidence that under high temperature conditions the typical insulin-glucose relationship is decoupled and insulin responds independently to thermal stress. Few studies have measured insulin in reptiles, especially in response to temperature extremes. Here we use garter snakes (*Thamnophis* spp.) to quantify the thermal response curve of insulin in reptiles under simulated heat stress and hibernation (cold stress) conditions. Our studies integrate and compare traditional measures (corticosterone) and metabolism with insulin providing evidence that, similar to mammals, the insulin response in reptiles acts independently of its role in glucose regulation under temperature extremes.

P2-205 HOLMES, IA*; RABOSKY, DL; DAVIS RABOSKY, AR; University of Michigan; *iholmes@umich.edu*

Snake and lizard gut microbiome metacommunities across host communities with variable diversity

Gut microbiomes are an ideal system for testing hypotheses about ecological community assembly, especially regarding the importance of diversity dependence in structuring communities. We compare gut microbiome richness across three communities that vary in host species richness to determine the effects of host community richness on microbiome richness. We sequence the hind-gut microbiomes from largely complete lizard and snake (squamate) communities across three latitudes (42 degrees north, 32 degrees north, and 12 degrees south) in the Western Hemisphere. The communities range from five host species, to 24, to 69, and the number of host higher taxa represented follows a similar increase towards the equator. Given the host gradient in species and phylogenetic diversity, gut microbiome lineage diversity might be expected to increase as well. However, we find no such increase either within or between hosts, at any level of microbial taxonomic structure. We explore the causes and consequences of this anti-gradient by examining the phylogenetic histories and ecological diversity of the hosts.

10-7 HOLOWKA, NB*; WYNANDS, B; DRECHSEL, T; HAILE, DW; OJIAMBO, R; OKUTOYI, P; TOBOLSKY, VA; YEGIAN, AK; ZIPPENFENNIG, C; MILANI, TL; LIEBERMAN, DE; Harvard University, Technische Universität Chemnitz, Moi University; *nick_holowka@fas.harvard.edu*

Plantar Calluses Provide Protection Without Trading-Off the Sensitivity of Fast-Adapting Mechanoreceptors

Habitually barefoot humans possess thick plantar calluses that develop in response to frictional stresses during walking and running. Because all humans were barefoot until relatively recently, plantar calluses should be viewed as a normal feature of human anatomy, yet we know surprisingly little about them. In this study we tested the common assumption that thick calluses tradeoff protection with a loss of sensory perception. We collected data from a large sample of adults from a Kalenjin-speaking population in western Kenya, including 35 habitually barefoot individuals and 46 habitually shod individuals. We used ultrasound to measure plantar skin thickness at the heel and first metatarsal head and found that habitually barefoot individuals have thicker epidermal skin than habitually shod individuals at both locations ($p<0.001$). We also measured skin hardness using a Shore durometer and found that hardness correlates with epidermal thickness across subjects at both the heel ($r=0.64$, $p<0.001$) and metatarsal head ($r=0.56$, $p<0.001$), with habitually barefoot individuals having harder skin ($p<0.001$). Finally, we tested the sensitivity of fast-adapting mechanoreceptors (types 1 and 2) at these locations using a standard vibration stimulus protocol. We found no relationship between plantar sensitivity and epidermal thickness at either location across subjects, even after controlling for age, sex and footwear use. This finding indicates that unlike footwear, calluses provide protection without loss of dynamic plantar sensitivity, making them a remarkable example of evolutionary engineering that allow us to walk and run barefoot safely.

S6-9 HOOD, Wendy*; WILLIAMS, Ashley; HILL, Geoffrey ; Auburn University ; *wrhood@auburn.edu*

Mitochondrial Replication Error and Senescence

In recent decades, ecologists and evolutionary biologists have investigated how various environmental challenges might lead to oxidative stress to evaluate the contribution of these stressors to aging processes. There is mounting evidence, however, that oxidative stress may play only a minor role in the decline in mitochondrial performance that is a hallmark of aging. Instead, there is a growing consensus in biomedicine that replication error, and not oxidative damage, is the source of most of the mitochondrial DNA (mtDNA) mutations that accumulate with aging. Replication error is a product of the process of making copies of mtDNA, where errors in copying and editing increase with the number of replication events. The processes responsible for mtDNA copying, editing, and those that alter the rate of replication are all subject to evolution by natural selection. Consequently, senescence via replication error may evolve within the context of the life history of a taxon. Given that different processes will contribute to variation in replication error and oxidative stress, it is critical that ecologists and evolutionary biologists begin to explicitly consider replication error in their measurements of the effects of and in their interpretations of the outcomes of environmental challenges. We will review those processes that alter mitochondrial performance with aging, discuss evidence that replication error is a crucial determinate of mitochondrial decline, and describe methods that can be used as indicators of replication error. And finally, we will discuss the role of that mitonuclear coadaptation plays in these processes.

127-5 HOOVER, A P*; MILLER, L A; University of Akron, University of North Carlonia; *ahoover1@uakron.edu*

The Emergence of Neuromechanical Resonance in the Control of Jellyfish Locomotion

In order for an organism to have an robust mode of locomotion, the underlying neuromuscular organization must be maneuverable in a changing environment. In jellyfish, the activation and release of muscular tension is governed by the interaction of pacemakers with the underlying motor nerve net that communicates with the musculature. This set of equally-spaced pacemakers located at bell rim alter their firing frequency in response to environmental cues, forming a distributed mechanism to control the bell's muscular contraction. When turning, pacemakers induce an asymmetrically timed contraction with the bell musculature. In this work, we explore the control of neuromuscular activation with a model jellyfish bell immersed in a viscous fluid and use numerical simulations to describe the interplay between active muscle contraction, passive body elasticity, and fluid forces. The fully-coupled fluid structure interaction problem is solved using an adaptive and parallelized version of the immersed boundary method (IBAMR). This model is then used to explore the interplay between the speed of neuromechanical activation, fluid dynamics, and the material properties of the bell.

85-6 HOPE, SF*; DURANT, SE; ANGELIER, F; HALLAGAN, JJ; MOORE, IT; KENNAMER, RA; HOPKINS, WA; Virginia Tech, University of Arkansas, Centre d'Etudes Biologique de Chizé, France, Stockton University, New Jersey, University of Georgia; *shope@vt.edu*

Incubation Behavior is Related to Prolactin and Egg Temperature in a Wild Bird

To maximize fitness, parents must tradeoff time and energy between parental care and self-maintenance. Factors such as hormones, clutch size, acute stressors and the external environment can influence parental care, which can then affect offspring development. In vertebrates, prolactin (PRL) and corticosterone (CORT) are two important hormones for parental investment because they stimulate parental care and mobilize energy, respectively, and can mediate the response to stressors. One of the most important parental care behaviors in birds is incubation, since small changes in egg temperature have large effects on offspring. To investigate how hormones may mediate incubation behavior, we collected baseline and stress-induced (30 min after capture) blood samples from female wood ducks (*Aix sponsa*) at the start and end of egg incubation. We also measured incubation behavior and temperature using artificial egg loggers. As expected, PRL decreased and CORT increased after 30 min of capture and restraint. Interestingly, PRL levels were higher at the end than the start of incubation and stress-induced PRL levels were positively related to the daily percentage of time spent incubating eggs. Further, the percentage of time spent incubating predicted the average and variability in egg temperature, after accounting for clutch size and ambient temperature. These results suggest that PRL increases as parental investment increases, that a dampened PRL stress response may be associated with the decision to stay on the nest despite stressors, and how parental behaviors may ultimately influence offspring fitness by modifying the early developmental environment.

125-1 HORN, KM*; LIAUTAUD, KA; CONRAD, CL; TELANDER, KJ; ZIPPAY, ML; HARDY, KM; Cal Poly SLO, Sonoma State Univ.; *kmhorn@calpoly.edu*

Are there distinct metabolic phenotypes in common acorn barnacles Balanus glandula across the intertidal zone?

Intertidal organisms live in one of the most physiologically stressful habitats on the planet. Daily tidal cycles result in predictable, often severe fluctuations in abiotic factors (e.g., temperature, oxygen, salinity, pH). The relative magnitude and degree of variability of environmental stress, however, differs between intertidal zones, with the most extreme physiological stress likely experienced by high intertidal organisms. We therefore hypothesize that sessile conspecifics from different intertidal positions (i.e., low, mid, high) will have distinct ‘metabolic phenotypes' (i.e., baseline metabolic capacity and performance). To investigate this hypothesis, we collected common acorn barnacles, *Balanus glandula*, from low, mid and high intertidal zones in San Luis Obispo Bay, CA and measured a suite of biochemical (lactate dehydrogenase and citrate synthase activity), physiological (O_2 consumption rates, body size), and behavioral (cirri beat frequency, time operculum open) measurements at a common seawater temperature; 13°C in an attempt to characterize distinct intertidal position-driven metabolic phenotypes. Preliminary data revealed that high intertidal barnacles reach larger body sizes and have greater size-corrected oxygen consumption rates than those in the mid or low intertidal. Further, high intertidal barnacles have lower cirri beat frequencies and tend to remain open longer than barnacles in the mid and low zones. (Biochemical enzyme assays are currently underway.) These initial data support the idea of distinct metabolic phenotypes across the intertidal, and may suggest that *B. glandula* from different tidal positions have variable capacities to accommodate environmental change.

68-2 HORNER, AM*; AZIZI, E; ROBERTS, TJ; Cal State University, San Bernardino, Univ. of California, Irvine, Brown University; *ahorner@csusb.edu*

Passive muscle stiffness is correlated to in vivo muscle operating lengths

The operating length of a muscle during movement is a key determinant of its ability to produce force *in vivo*. Relative to the peak force plateau on a force-length curve, muscles that operate at longer lengths can produce higher forces throughout shortening, whereas muscles that operate at shorter lengths may be safer from sudden length perturbations and subsequent damage. As connective tissues change during aging, the mechanics of muscle length changes must also be affected. In this study we investigated the relationship of *in vivo* muscle operating length to *in situ* muscle properties in young (7 mos) and aged (30-32 mos) rats. Specifically, we examined the relationship of passive and active force-length relationships to muscle operating length during walking and trotting using fluoromicrometry. Muscle lengths were measured via small (< 1.0 mm) radio−opaque markers surgically implanted into the muscle and placed along muscle fascicles in the medial gastrocnemius, and markers were visualized during locomotion and *in situ* muscle contractions using high−speed x−ray videography. An active force-length relationship was characterized *in situ* by tetanically stimulating the muscle while visualizing the same muscle markers and simultaneously measuring force with an ergometer. Despite inter-individual variation in passive muscle stiffness, rats of both age groups demonstrated a clear (R2>0.7; p<0.001) relationship between passive stiffness and *in vivo* operating length. Our results suggest that, rather than tuning muscle lengths relative to an optimal force plateau, the operating lengths of locomotor muscles during sub-maximal activity do not exceed lengths that result in significant passive forces.

P1-152 HORR, DM*; IVANOV, BM; PAYNE, AA; ROUZBEHANI, M; VEGA, J; WANG, H; JOHNSON, MA; Trinity University, San Antonio; *dhorr@trinity.edu*

Behavioral Repeatability in the Bark Anole, Anolis distichus, Across Social Contexts

Many species express variation in behavioral types, such that individuals within a population may consistently express a type of behavior that differs from others. Yet often behavior is context-driven, where individual responses may differ when individuals are presented with a potential competitor versus a potential mate. Behavioral syndromes occur when individuals who fall within one behavioral type continuously present this behavior type across a number of different situations, regardless of context. Here, we studied the repeatability of male *Anolis distichus* lizard behavior to examine whether social display or locomotor behaviors are consistent across multiple social contexts. Additionally, we analyzed whether physiological or morphological variation across males is associated with the repeatability of these behaviors. In this study we performed two replicates of each of three trials (male-female, male-male, and nonsocial Open Field Tests) to record social behaviors (dewlap and push-up displays), and general movements. We then measured the mass, head size, dewlap area, and SVL (snout-vent-length) of each lizard, and collected physiological measures of liver mass, fat pad mass, and hematocrit levels. We found that individual *A. distichus* behaviors were generally consistent within each type of trial, and their average movement and display behaviors were consistent across the different tests. We did not find support for associations between physiological or morphological traits and behavior. In sum, these lizards exhibited behavioral consistency both within and across social contexts, raising the possibility that these traits may be associated with a behavioral syndrome.

S11-10 HOULE, D.*; FORTUNE, R.; JONES, LT; Florida State University; *dhoule@bio.fsu.edu*

Excavating burden: revealing the causes of stasis in allometry

Morphological allometry is a striking example of a certain sort of evolutionary stasis. Organisms that vary in size adopt shapes that are predictable from that size alone. There are two major hypotheses to explain this. It may be natural selection strongly favors each allometric pattern, or that organisms lack the development and genetic capacity to produce variant shapes for selection to act on. Using a high-throughput system for measuring the size and shape of Drosophila wings, we documented an allometric pattern that has been virtually unchanged for 40 million years. We performed an artificial selection experiment on the static allometric slope within one species. In just 26 generations, we were able to increase the slope from 1.1 to 1.4, and decrease it to 0.8. Once artificial selection was suspended, the slope rapidly evolved back to a value near the initial static slope. This result decisively rules out the hypothesis that allometry is preserved due to a lack of genetic variation, and provides evidence that natural selection acts to maintain allometric relationships. On the other hand, it seems implausible that selection on allometry in the wing alone could be sufficiently strong to maintain static allometries over millions of years. This suggests that a potential explanation for stasis is Riedl's concept of burden, where selection in favor of a particular state is spread over the many pleiotropic effects. This seems likely in the case of allometry, as the sizes of all parts of the body may be altered when the allometric slope of one body part is changed. Unfortunately, hypotheses about pleiotropy have been very difficult to test. We lay out an approach to begin the systematic study of pleiotropic effects using genetic manipulations and high-throughput phenotyping.

P2-199 HOUTZ, JL*; RECEVEUR, JE; PECHAL, JL; BENBOW, ME; HORTON, BM; WALLACE, JR; Millersville University, Michigan State University; *jlh498@cornell.edu*

Starling Gut Microbial Community Changes Through Decomposition: A New Approach for Wildlife Forensics

In the context of wildlife forensics, knowing the time interval from the moment of death to discovery or the postmortem interval (PMI) range can reduce the number of potential suspects to those without a viable alibi for the time of the crime. A PMI range can be determined by tracking the temporal succession of the microbial communities associated with a decomposing body. We characterized temporal shifts in the taxonomic and *in silico* predicted functional composition of the postmortem microbiome associated with the gut tracts of European Starling (*Sturnus vulgaris*) carcasses over three days. The objectives for this study were to: 1) characterize the gut microbiomes of starlings antemortem and postmortem; 2) compare microbial taxonomic and functional composition among different gut tract regions including the small and large intestines, ceca, and cloaca; and 3) determine if and how avian gut microbial taxonomic and functional composition changed in a repeatable and predictive pattern during decomposition. We detected significant differences between antemortem and postmortem samples in both taxonomic and functional composition after 24 hours, but the microbiome remained stable between 24 and 72 hours postmortem. There were significant differences between gut tract regions in both taxonomic and *in silico* predicted functional composition antemortem, but sample location microbiomes converged after death. Our findings are the first to describe the postmortem microbiome in an avian model, and provide preliminary data for the potential forensic utility of the avian gut postmortem microbiome in estimating time of death.

37-3 HOWARD, C.C.*; LANDIS, J.B.; FOLK, R.; BEAULIEU, J.M.; CELLINESE, N.; University of Florida, University of Riverside, Florida Museum of Natural History, University of Arkansas, Fayetteville, Florida Museum of Natural History; *cchoward@ufl.edu*

Digging for answers: the causes and consequences of geophytism in the monocots

Geophytes are plants with resting buds that are located beneath the soil surface typically in the form of rhizomes, corms, tubers or bulbs. These adaptations are hypothesized to have evolved in response to an increase in climatic seasonality, and are highly diverse in areas like the Mediterranean Basin or the Cape Floristic Region. In addition to these hotspots, geophytes can be found across the globe and are distributed across the plant tree of life. However, geophytic taxa are most prevalent within the monocot clade and include members such as ginger, taro, arums and tulips. Interestingly, some clades appear to be more labile in underground morphology shifts while others are not. Despite this breadth of diversity, the majority of studies on geophytes have primarily focused on select clades or geographic areas; thus, broad phylogenetic inferences of these traits have yet to be carried out. Furthermore, it has been suggested that the switch to geophytism may promote increased diversification rates but this hypothesis has yet to be tested. Here, we investigate potential factors that have given rise to the diversity of underground organs that we see today. We ask: Are there any climatic variables that favor certain geophytes? How have these factors influenced the evolution of these taxa? Does geophytism promote diversification? Using a comprehensive phylogeny and global climate data, we investigate these questions in the monocot clade. While fine scale analyses are useful, unearthing broad evolutionary patterns of geophytism will allow for a more holistic view of the potential factors influencing their evolution, which is of utmost importance in order to promote further research of these complex structures and taxa.

P2-3 HOWARD, CC*; CELLINESE, N; University of Florida; *cchoward@ufl.edu*

Breaking Ground on Bulb Evolution in the Monocots

Plant bulbs are underground organs with resting buds located on a reduced stem surrounded by layers of leaves and/or scales. This trait has evolved at least eight independent times within the monocots. Iconic examples include tulips, hyacinths and onions. Although all bulbs are thought to be a common structure, there exists a diversity of bulb scale morphologies. Bulbs can be comprised of leaf bases, swollen scales, swollen leaf bases, or both leaf bases and scales. Additionally, external bulb morphology varies across taxa. Some are covered with a paper-like outer covering (i.e. tunicate bulbs [e.g., onions, tulips]) and others lack this trait (i.e. imbricate bulbs [e.g., lilies]). Furthermore, bulb size (i.e. diameter) varies greatly both within and among clades, with the Amaryllidaceae housing some of the largest bulbs and the Poaceae the smallest. The multiple independent origins of this trait provide researchers with an excellent opportunity to study the evolutionary and developmental processes that have promoted the evolution of these seemingly similar, yet morphologically diverse, structures. To generate evolutionary hypotheses of bulb evolution, in this study, we quantified bulb size variation across the monocots, and investigated potential underlying causes of size evolution.

103-3 HOWE, SP*; LEFFLER, D; ASTLEY, HC; Univ. of Akron; *sph43@zips.uakron.edu*

Midlines in motion: Connecting Midline Curvature Dynamics to Heading Change and Center of Mass Deflection in Fishes

Fish maneuverability is a complex and dynamic behavior. Most research on fish maneuverability has focused on stereotyped maneuvers such as the C-start escape response, but routine maneuvers have highly variable kinematic outcomes. Prior studies identify preparatory and propagating stages of the turn, but have not linked body deformations in the fish to outcomes of the turn like heading change and center of mass deflection. Using high-speed video and image analysis software, we provide a detailed description of the midline kinematics of the giant danio (*Devario aequipinnatus*) and track the orientation of the fish as well as the center of mass over the course of a maneuver. In all turns, regardless of experimental treatment or heading change magnitude, we observed an anterior to posterior propagating pulse of curvature along the midline of the body. This behavior can be modeled as a transient pulse with quantifiable amplitude, width, and velocity. We focus primarily on the relationship between center of mass deflection and curvature pulse statistics to establish functional links between the behavior of the fish's body and the direction changes of the fish. We found that total heading change is correlated with average curvature, and rate of heading change correlates with pulse velocity. Maximum linear acceleration is correlated with pulse velocity, and angular displacement of center of mass correlates with average body curvature. We have observed more complex maneuvers where fish link pulses in quick succession. It appears that the general form of the pulse is conserved across these maneuvers and combining pulses augments the final outcome of the turn. A pulse based model of fish turning seamlessly integrates with steady swimming while also providing a mechanism to produce complex maneuvers.

25-2 HOWELL, CR*; ANDERSON, RC; DERRYBERRY, EP; University of Tennessee, Knoxville, Florida Atlantic University; *clararudihowell@gmail.com*

Solving is Sexy: the role of problem-solving ability in mate choice in zebra finches (Taeniopygia guttata)

Animals should prefer mates with better problem-solving ability, but it is unclear (1) how a male can advertise his problem-solving ability, and (2) whether a female's problem-solving ability affects her preference. Many sexual signals are unlearned and thus unlikely to reflect cognitive or personality traits that also impact problem-solving ability. One exception is bird song, which is learned by both males and females. We tested two hypotheses involving problem-solving ability and mate choice: (1) male song is an honest signal of problem-solving ability, and (2) problem-solving ability affects female mate preference. One group of male and female zebra finches (*Taeniopygia guttata*) was housed together and given a novel foraging task, and another group of females was housed separately. Males were divided into Solvers and Non-Solvers and their song was recorded. Female preference for Solver vs. Non-Solver song was assayed using a two-choice operant conditioning set-up. In the first experiment, we tested preference in females not housed with males and found a group-level preference for Solver song that was unexplained by song complexity. In a second experiment we tested preference in females who were housed with the males. We found no group-level preference for Solver song, but saw evidence of assortative mating between heavier females and Solver males. Also, females that solved the task in fewer trials showed stronger preferences for conspecific over heterospecific song in the training portion of the preference assay. Together these results indicate that male song may signal problem-solving ability in the zebra finch and that female problem-solving ability and mass affect different aspects of mate choice.

66-2 HOWEY, C.A.F.; University of Scranton; *christopher.howey@scranton.edu*
Restoration of Timber Rattlesnake Rookeries: Efficacy of Daylighting Management
The range of Timber Rattlesnakes (*Crotalus horridus*) extends further north than most other rattlesnakes. In these colder, northern latitudes, gravid female *C. horridus* must use rare, open habitats (rookery sites) in order to elevate body temperatures necessary for successful embryonic development. Unfortunately, many of these rookery 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 three summers (2016, 2017, 2018) we radio-located gravid females at six rookery sites; four of which have become overgrown with vegetation. At each site, we monitored available operative temperatures, canopy cover, and presence of potential predators. We determined the body temperature of females throughout the entire summer, behaviors, date of parturition, and estimated litter size. During the winter 2016, we removed trees 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 (pre-Daylighting), gravid females at more enclosed rookery sites dropped litters at a slightly later date, abandoned rookery sites, aborted their litters, and mothers suffered increased mortality. Following Daylighting management, we gathered evidence for increased reproductive success and improved thermal conditions. However, risk of predation may also be higher. We 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.

92-7 HSU, S.J.*; SEBER, E.; MCFARLAND, C.; CHENG, B.; Pennsylvania State University; *buc10@psu.edu*
Visual Speed Control in Pitch-Constrained Blue Bottle Flies in a Motorized Magnetically-Levitated Flight Mill
Flies rely heavily on retinal image motion to control their flight speed. In the presence of changes in wind speed or background visual motion, they are able to uphold a consistent retinal image velocity within their locomotor constraints by varying their airspeed. Flies regulate flight speed primarily by adjusting their body pitch - a mechanism frequently characterized as helicopter model. However, it is unknown whether the flies are able to regulate their speed via only the modulation of wing kinematics in the absence of pitch maneuver, or to what extent the visual control can regulate speed under this locomotor constraint. In this study, we investigated the visual speed control of blue bottle flies (Calliphora vomitoria) flying at zero body pitch in a magnetically-levitated flight mill, with motorized cylindrical walls displaying grating patterns. We perturbed the flies' retinal image motion via spinning the grating patterns of different spatial frequencies (22, 11, and 0 1/rev) at different angular velocities. Results showed that at a fixed body pitch flies were able to compensate the image-motion perturbation by adjusting their airspeed up to 20%, thereby to maintain the retinal image velocity relatively constant (0.47+/-0.03 rad/s). However, the compensation weakened as their airspeed plateaued when the image-motion perturbation became large, indicating that flies were unable to further increase or decrease their speed due to locomotor constraint. The compensation gain, i.e., the ratio of airspeed changes and image-motion perturbation, was largest at the intermediate spatial frequency.

P3-48 HSU, S.J.*; WANG, J.; DONG, H.; CHENG, B.; Pennsylvania State University, University of Virginia; *buc10@psu.edu*
Effects of Wing Flexibility on the Aerodynamic Performance of Blue Bottle Flies Flying in a Magnetic-Levitated Flight Mill
Insect wings can deform substantially during flight, exhibiting patterns of camber and twist that vary throughout a wingbeat cycle. Such deformations have profound implications on the aerodynamics and flight performance of insect flight, which, however, are difficult to quantify, especially for free flying insects. In this study, we measured the flight performance and kinematics of blue bottle flies (Calliphora vomitoria) flying steadily in a magnetic-levitated (MAGLEV) flight mill, including the flight speed, forward thrust, and wing surface deformations via combined high-speed videography and marker-less surface reconstruction. We then analyzed the underlying aerodynamics by simulating the flight kinematics using a high-fidelity, three-dimensional, computational fluid dynamics simulation, and compared the aerodynamic performance of the deformed wings and the undeformed wings. During steady flight, the flies' wings had positive camber during downstroke and negative camber during upstroke, i.e., creating a pocket with an opening towards the stroke direction in both half strokes. The wings also exhibited continuous spanwise twists, leading to decreasing angle of attack from wing root to tip. Mean thrust generation in deformed wings increased by 26% on average compared with that of undeformed wings, as the deformation reduced the drag during downstroke and increased the thrust during upstroke, primarily due to the forward force-vectoring. Wing deformation also significantly enhanced the thrust-generation efficiency by 32%. Our results revealed the indispensable role of wing flexibility in the insect flight performance and also could have critical implications on the design of flapping-wing micro-air-vehicles.

S4-2 HU, David L.; Georgia Tech; *hu@me.gatech.edu*
How ants behave like a fluid and a solid
Fire ants can link their bodies together to build waterproof rafts to survive floods. In this talk, I will discuss the structures that fire ants build, and how these structures are limited by the strength of the connections between the ants. We use time-lapse photography and x-ray scanning to characterize the construction of rafts and towers. We relate the shapes observed to the rheology of the ants, their viscosity and their elasticity, which are measured using a rheometer, a device which usually characterizes the properties of chocolate and yogurt.

P1-46 HUBER, D.*; CUNNINGHAM, T.; CASARETO, S.; AMPLO, H.; FORD, J.; DECKER, S.; MARA, K.; The University of Tampa, New Jersey Institute of Technology, University of South Florida, University of Southern Indiana; *dhuber@ut.edu*

Fluid Dynamics of Hammerhead Shark Locomotion

The hammerhead sharks are characterized by an extremely unusual head morphology, the cephalofoil, the function of which has long been debated. While advantages have been identified for sensory systems, the role of this structure in locomotion is poorly understood. Therefore, we sought to quantify the effect of cephalofoil shape on fluid drag. The heads of six hammerhead species of varying cephalofoil morphologies were CT scanned, digitally reconstructed, and 3D printed. Fluid drag was then experimentally measured on each head model while varying angle of attack (i.e., pitch, yaw, roll from 0-35 degrees) in a recirculating flume. Drag coefficient, a measure of the effect of shape on drag, was derived from these measurements. Preliminary results indicate that fluid drag is affected by cephalofoil shape. The largest mean drag coefficient for pitch was associated with the largest, most ancestral cephalofoil of the winghead shark *Eusphyrna blochii*, whereas the smallest mean drag coefficient for pitch was associated with the smallest, most derived cephalofoil of the bonnethead shark *Sphyrna tiburo*. Mean drag coefficients were linearly related to cephalofoil width, indicating that drag reduction may be a selective pressure in the reduction of cephalofoil size. All species also demonstrated a reduction in drag force and drag coefficient at positive pitch angles, which supports the observation that sharks maintain positive angles of attack during swimming to generate lift with the ventral body surface.

P1-26 HUBER, D.*; TRAVIS, K.; GRACE, M.; FORD, J.; DECKER, S.; The University of Tampa, California State University Long Beach, National Oceanic and Atmospheric Administration, University of South Florida; *dhuber@ut.edu*

Structural Mechanics of Cookie Cutter Shark Jaws

Sharks exhibit a wide array of feeding mechanisms, behaviors, and ecologies, among which the cookie cutter sharks (Isistius spp.) are rather unique. Their semi-circular, scoop-shaped lower jaw bears teeth fused into a saw blade, which is used to excise circular flesh plugs from large fishes and marine mammals via longitudinal rotation of the body. To identify the extent to which these unique anatomical attributes facilitate their unique feeding niche, Finite Element (FE) models of the jaws of the large tooth cookie cutter shark *Isistius plutodus* and spiny dogfish *Squalus acanthias* were developed from CT scans; the spiny dogfish represents a generalized shark feeding mechanism for comparison. Models for both species were then virtually manipulated to represent all possible character states, resulting in 7 models per species (jaws, jaws + fused/unfused functional teeth, jaws + fused/unfused replacement teeth, jaws + fused/unfused functional teeth + fused/unfused replacement teeth). FE simulations were run to determine jaw performance during normal biting (i.e., forces applied perpendicular to the jaw surface) and rotational biting (i.e., forces applied parallel to the jaw surface), and jaw stress and strain energy were determined. Preliminary analyses for the cookie cutter shark indicate that jaw stress and strain energy are 1) lower during rotational biting than during normal biting, and 2) lower when fused functional and replacement teeth are present, suggesting structural adaptation for the unique feeding niche occupied by this shark.

105-5 HUBICKI, CM*; DALEY, MA; Florida State University, Royal Veterinary College; *hubicki@eng.famu.fsu.edu*

An optimal control model of bipedal leg swing for predicting gait duty factor in cursorial birds

Bipedal runners, when changing their speed, can theoretically choose many combinations of stride length (SL), stride frequency (SF) and duty factor (DF). We seek a theoretical framework to predict the combination of SL, SF and DF used by individual species for a given speed. Previous work has been successful in using math models combined with optimal control methods to predict locomotion features by minimizing energy cost. For instance, a prior model showed that work-optimal control of a damped-spring-mass leg model could predict the asymmetrical stance dynamics of ground-running birds. This work builds atop the previous model by exploring additional physiologically relevant control constraints and mechanical components for the model; this is an attempt test plausible incentives for bipeds to change duty factors with speed. We systematically modeled the effects of power limits, force limits, and kinematic limits on optimal gait duty factor, and all of which found a grounded gait (DF=0.5) to be energetically optimal regardless of speed. However, including an inertia-based cost to leg swing and minimizing mechanical COT yielded a decreasing duty factor with speed- similar to bipedal animals. This work further compared these model predictions to the experimental duty factors of helmeted guinea fowl (*Numida meleagris*) during steady running across speeds. By fitting the three free model parameters (spring stiffness, damping constant, and leg inertia), the mathematical prediction matched the SL, SF, and DF of our guinea fowl data set from 1.3m/s up to 3.1 m/s running. We aim to use this model to further predict bipedal locomotion features such as gait transitions and gait adaptations to non-rigid terrain.

83-3 HUDSON, DM; The Maritime Aquarium at Norwalk; *dhudson@maritimeaquarium.org*

Behavioral and Metabolic Temperature Optimum Determination in an Andean Freshwater Crab.

Behavioral analysis of stress is often the best acute measure of maladaptive conditions. Animals have sensory systems that react to aversive conditions and allow the animal to mount an appropriate behavioral response. In the case of the endemic Colombian freshwater crab, *Neostrengeria macropa*, the effects of temperature over the next century combined with increased risk from human development on the Bogotá Plain could have an impact on its long-term survival. Additionally, there are over 100 other freshwater crabs in the country that could be at risk if the RCP 8.5 IPCC scenario comes to pass. Previous behavioral work indicated that the freshwater crab, N. macropa, has a probable temperature preference range of 10.5°C to 26°C (Hudson et al., 2016). The respirometry results highlight the importance of coupling behavioral quantification with respirometry data. Even though activity declines for the 28°C temperature treatment in the behavioral study, respiration rate continued to increase, meaning that the organism is behaviorally compensating by decreasing its exploratory behavior.

P1-276 HUIE, JM*; SUMMERS, AP; KOLMANN, MA; University of Washington, George Washington University; *jmhuie@uw.edu*
Body shape and feeding morphology explain ecological differences in riverine herbivorous fishes
Herbivorous fishes may feed on any combination of stems, leaves, flowers, seeds, fruits, and nuts of diverse aquatic plants, as well as algae. In the Neotropics, most pacus, the herbivorous cousins of piranhas, eat a combination of these plant constituents, which vary in their accessibility, material, and nutritional quality. Additionally, pacu diets fluctuate across ontogeny, and with seasonality and flowering demography of their prey. Several species of pacus are phytophagous, a curious kind of herbivore that feeds almost exclusively on Podostemaceae, or riverweed plants, which only occur in rapids, a challenging environment for fishes to live in. The degree to which pacus feed on riverweed varies from obligate year-round consumption to strictly seasonal and facultative feeding. Obligate phytophages feed heavily on riverweed and occur in the rapids, while facultative phytophages only consume riverweed during seasons with low flow. Does ecological specialization (diet) beget morphological specialization in the feeding apparatus of phytophages? We used micro-computed tomography (µCT) scanning to compare functional feeding traits among 24 species of serrasalmids, 3 of them obligate phytophages. We also compared body shape between pacus using geometric morphometrics to identify potential locomotor adaptations for rheophily. Obligate phytophages don't have distinct jaw mechanics from more generalized herbivores, but they do have the dentition and slicing jaw action more suited to shearing fleshy plant material than other pacus, which have jaws built for crushing seeds. Unrelated obligate phytophages are also converging on similar body shapes that are distinct from sympatric herbivores. Phytophagy involves more drastic changes to body shape than to feeding morphology, suggesting that body shape has equally important ties to diet as feeding morphology.

P1-178 HUMFELD, SC*; GERHARDT, HC; SARAH, Humfel; University of Missouri; *humfelds@missouri.edu*
Perceptual biases and the evolution of acoustic signals with multiple elements
The acoustic advertisement signals of many animals comprise a single sound repeated in a monotonous fashion. Multi-element signals, in which sounds with different acoustic parameters are produced closely together in time, are observed in a wide diversity of species across taxonomic groups. While increasing signal complexity may communicate greater information content, it is unclear what factors might effect the evolution of increasing signal complexity. In this study, we tested the hypothesis that acoustic preferences exhibited by females during mate-choice might constrain the evolution of increased call complexity. In a species where males produce only simple trilled calls (*Hyla versicolor*), we presented females with a choice between a natural, single-element call and an artificial, two-element signal. Artificial signals were generated by appending a computer-synthesized tone-burst to a normal trill. We were specifically interested in the main and interaction effects of: 1) the position of the artificial appendage relative to the trill; 2) the duration of the trill; 3) the duration of the appendage; 4) and the silent interval (SI) between the two call elements on preferences. The results of this study confirm that two-element signals with following appendages were generally attractive, but especially so when the duration of the trill is short. We observed interaction effects between the appendage position and both the SI and the duration of the appendage. In a leading position, longer appendages and appendages with a longer SI resulted in particularly unattractive multi-element calls. We conclude that receiver psychology is likely to be an important constraint on the evolution of increasing signal complexity. The generality of our results requires additional comparative studies of species with single-element signals.

122-4 HUND, AK*; TURBEK, SP; PAULI, CS; SAFRAN, RJ; TAYLOR, SA; University of Minnesota, University of Colorado; *ahund@umn.edu*
Early Environment and Condition Dependence in a Lifelong Sexual Signal: Gene Expression and Melanin Color in Barn Swallows.
Female preferences for male sexual traits are thought to be adaptive because they allow females to gain information about potential mates. The condition dependence of sexual traits is hypothesized to maintain the honesty of this information, where only healthy males who are well adapted to their environment can express the most elaborate traits. Melanin-based sexual traits, however, have long been thought of as strictly genetically controlled and there is often a lack of condition dependence with trait expression in adults. One explanation is that condition dependence for some melanin traits is limited to certain time periods, such as early development. In barn swallows *Hirundo rustica erythrogaster*, where melanin breast plumage is sexually selected, the majority of color variation can be attributed to variation in the developmental environment, yet color changes little within individuals as adults, despite annual molting of feathers. To understand the gene by environment interactions that generate this pattern, we cross-fostered eggs at the start of incubation and manipulated parasites in nests. We also collected data on maternal investment in egg composition and incubation, as well as nestling condition and physiology. Developing feather quills were collected from experimental nestlings for RNA analysis and compared with the color of emerged feathers when nestlings fledged. From these data, we identify how gene expression and environmental variation during development shape melanin color expression. This work provides new insight into the condition-dependence of melanin traits during development, and what females gain by using melanin-based signals during mate choice.

P1-33 HUNG, Y-T; LIN, T-Y; SHIH, M-C; CHI, K-J*; National Chung-Hsing University, Taiwan; *kjchi@phys.nchu.edu.tw*
Functioning Mechanism and Detachment Process of the Tentacular Suckers in Cuttlefish Sepia pharaonis
Octopus and cuttlefish use muscular suckers to capture the preys; while octopus are known to generate suction force by muscle contraction, the functioning mechanism of cuttlefish suckers remains unexplored. Here we examined the suction performance and detachment process of tentacular suckers of cuttlefish *Sepia pharaonis*. Suction without muscle contraction implies a passive mechanism; pressure difference might be created by pulling the stalk. To examine the role of sucker ring, we compared suction performance with ring intact, removed, and replaced. Results suggest that the ring is critical presumably in distributing the pulling stress for better contact. However, insertion of a stiffer ring could not enhance its performance. Although intermittent leakages were observed, pressure difference still generated, implying self-sealing even with imperfect contact. On substrates of varying roughness, suction performance remains similar. Synchronous recordings of suction force, sucker deformation, and internal bubble formation during attachment-detachment process reveal that bubbles could change the force-deformation curve; because gas deforms more easily than the liquid, bubble expansion could retard pressure increase hence to prolong attachment duration. This study demonstrates the functioning mechanisms of tentacular suckers of cuttlefish. The identified mechanical features fit their predation strategy for capturing fast-moving preys. Unlike artificial suckers, cuttlefish suckers perform well on rough, curved, or even soft surfaces, which provide insights for future bio-inspired design of underwater attachment devices.

P2-213 HUNG, A*; KENALEY, CP; Boston College; *hunga@bc.edu*

Vertebral Stiffness in Ray-finned Fishes: Contrasting Material Properties Between Swimming Modes and Body Region

The axial skeleton of fishes plays an important role in developing thrust during undulatory swimming. A considerable number of studies have focused on the established role of axial stiffness in modulating undulatory dynamics, including propulsive wavelength. Few studies, however, have addressed whether axial skeletal stiffness varies across species with different swimming styles defined by a spectrum of propulsive wavelengths. In addition, recent work in our lab indicates that propulsive wavelength increases as it passes through the fish body. In this study, we set out to (1) evaluate whether vertebral stiffness varies between species of different swimming modes including classically defined anguilliform, subcarangiform, and carangiform locomotor styles; and (2) whether vertebral stiffness contributes to the lengthening of the propulsive wave by a rostrocaudal gradient of increased stiffness. To this end, we measured the compressive stiffness of vertebrae using custom-built material-testing units along the vertebral columns of six species of teleost fishes: American eel (*Anguilla rostrate*), brook char (*Salvelinus fontinalis*), Florida pompano (*Trachinotus carolinus*), yellow perch (*Perca flavescens*), Chain Pickerel (*Esox niger*), and lookdown (*Selene vomer*). We found that the stiffness of the vertebral column increases rostrocaudally in all species and that overall vertebral stiffness is lowest is anguilliform swimmers and highest in carangiform swimmers. Taken together, these results indicate the importance of passive tissues in modulating swimming dynamics in fishes.

106-1 HUNTER, FK*; KAPHEIM, KM; Utah State University; *franceskhunter@gmail.com*

The molecular and physiological underpinnings of life history tradeoffs in a socially flexible bee

The evolution of biological complexity is rooted in life history tradeoffs, in which beneficial change in one trait (e.g., fertility) is associated with a detrimental change in another (e.g., longevity). These tradeoffs are seen at all levels of biological organization, from single-celled and multicellular organisms to groups of cooperative individuals (i.e., a social insect colony). A universal-yet poorly understood-feature of transitions in biological complexity from the individual to a group is the decoupling of life history tradeoffs at the individual level and recoupling at the higher level. For example, queens of social insect colonies show escape from tradeoffs, as they are both long-lived and highly fertile, but these tradeoffs are recoupled at the colony level, which must balance resource allocation between colony maintenance and brood production. A potential mechanism for the life history tradeoff decoupling observed in social insect queens is a molecular rewiring of pathways linking the stress response to reproduction. Species with facultative social behavior provide a unique opportunity to test this hypothesis, because life history tradeoffs are preserved in some individuals but decoupled in others, suggesting they hold the key to how mechanisms of tradeoff decoupling impact social evolution. We experimentally manipulated reproductive investment via endocrine treatments and observed immune investment response in a facultatively social bee, *Megalopta genalis* by measuring response in terms of mortality, ovary maturation, and nutritional stores. By illuminating the mechanisms of life history trade-offs in a flexibly social organism, our results provide valuable insight into how physiological ecology influences life history evolution.

109-5 HURD, PL*; DRISCOLL, RMH; RENN, SCP; University of Alberta, University of Rochester, Reed College; *phurd@ualberta.ca*

Differences in aromatase gene expression and promoter methylation in a cichlid with alternative male morphs.

For an animal to reproduce it must successfully develop either testes or ovaries, and the supporting behaviours to make use of them. In gonochoristic species, a developmental process of sex determination resulting in the decision to mature as either male or female is followed by a process of primary sexual differentiation ending in functional gonads, and processes of secondary sexual differentiation which produces the other morphological and behavioural traits. An adapted phenotype includes a whole range of physiological and behavioral traits which must develop to sexually differentiated endpoints to support the sex and reproductive strategy of the individual. Many species also show discrete variation in morphology and behaviour within a sex that represent alternative reproductive tactics (ARTs). A process very much like, or indeed a part of, sexual differentiation underlies the differentiation of these alternative morphs. Here we investigate promoter methylation and expression of two copies of the gene encoding the aromatase enzyme, in fry towards the end of the critical period of environmental sex determination. We also compare expression and promoter methylation among adult females and males of three different morphs.

P3-143 HUSAK, JF*; LAILVAUX, SP; Univ of St. Thomas, Univ of New Orleans; *jerry.husak@stthomas.edu*

Is the exercise response adaptive?

Superior locomotor performance is associated with advantages in terms of male combat success, survival, and fitness in a variety of organisms. In humans, investment in increased performance via the exercise response is also associated with numerous health benefits, such as decreased incidences of metabolic syndrome, cardiovascular disease, obesity, and diabetes, and aerobic capacity is considered to be an important predictor of longevity. One of the most striking aspects of exercise physiology is how similar the response to exercise is across vertebrate animals, suggesting that the response to exercise is both ancient and adaptive. However, no studies have tested whether non-human animals that invest in increased athletic performance through exercise realize a fitness advantage in nature. Previous work with green anole lizards showed that they respond to different forms of exercise training, and that enhanced performance results in tradeoffs in other systems, such as reproduction and immnuocompetence. We released sprint-trained, endurance-trained, and untrained-control male and female green anole lizards into isolated, urban islands in New Orleans, LA, USA and monitored their survival. We predicted that training would enhance survival during the active season, but that the associated maintenance costs of training would decrease survival overwinter compared to controls. We found that sedentary controls realized a significant survivorship advantage over all time periods compared to trained lizards. Our results suggest that locomotor capacity is currently optimized to maximize survival in green anoles, and that forcing additional investment in performance moves them into a suboptimal phenotypic space relative to their current environmental demands.

P3-138 IBRAHIM, AS*; HUND, AK; STEPHENS, JQ; WICKER, VV; TSUNEKAGE, T; SAFRAN, RJ; LEVIN, II; Agnes Scott College, University of Colorado - Boulder; *aibrahim@agnesscott.edu*

The effects of sex and growth rate on variation in nestling telomere length

Offspring growth rate and sex-specific development are key components of the natal life history stage. Nestling traits and stressors during this period can have long term fitness consequences. Telomeres, which are protective non-coding caps on the ends of eukaryotic chromosomes, shorten rapidly during development due to high rates of cell division and oxidative stress. Longer telomeres have been found associated with higher survival rates and better organismal performance. We examined the effects of nestling sex and growth rate on relative telomere length in North American barn swallow (*Hirundo rustica erythrogaster*) nestlings. Our study used a cross-foster design, where half of the eggs in experimental nests were switched with synchronously-laid eggs from other nests at the start of incubation. Nine days after hatching, nestlings were measured for body size and mass, and blood samples were taken for molecular sexing, quantification of relative telomere length, and for parentage analysis using microsatellite markers. At day twelve, morphological measurements were repeated to calculate growth rate. We used quantitative PCR to estimate relative telomere length in nestlings and found that male nestlings had relatively longer telomeres compared to female nestlings. Growth rate was not related to relative telomere length in either sex.

P1-296 IDEC, JH*; FISHER, BL; Hendrix College, Conway , California Academy of Sciences, San Francisco; *idecjj@hendrix.edu*

Characterizing Color Diversity in Ants Using Databases and Image Analysis

Ants (Order Hymenoptera, Family Formicidae) are a widespread and diverse group of insects. Despite many years of research in ant ecology and evolution, the diversity of color in ants as a group has not yet been closely examined or explained. In doing so we used a dataset consisting of ~50k images from the ant specimen database AntWeb. Images of ant heads were first segmented from their backgrounds using an active contour algorithm. The RGB colors of pixels in the segmented region were averaged and assigned to that specimen. We then tested for the effects of phylogeny, caste, microhabitat, and environment on these colors. Color metrics included HSL lightness and proxies for pigment saturation devised from Euclidean distance in the HSV color space. We hypothesized that darker and more heavily pigmented ants would be found in habitats prone to higher UV exposures or colder temperatures due to the UV-shielding and heat-absorbing properties of melanin. We found that genera, primary ant castes, and ants living in different microhabitats showed statistically significant differences in lightness and pigment saturation. Despite a strong signal for color at the genus level, ants as a group showed on average decreased lightness and greater pigmentation under conditions where they would be more likely to be exposed to sunlight. Queens and males, which often mate in sun-exposed locations, were darker on average than workers. Ants collected from trees were also darker than those from the litter or underground. Caste and microhabitat effects compared between genera and possible global effects of UV and temperature are still under investigation at the time of writing.

8-5 INGLE, DN*; PORTER, ME; Florida Atlantic University; *dingle2014@fau.edu*

Mechanical behavior of vertebral trabecular bone varies regionally and ontogenetically in the Florida manatee (Trichechus manatus latirostris)

Trabecular bone forms a porous architecture that changes in vivo to support mechanical demands on the body and can reflect the degree of an animal's species-specific precociality; skeletons must be stronger and stiffer in animals that are mobile soon after birth. Previous studies have shown that secondarily adapted aquatic mammals have vertebral microarchitecture and loading regimes that differ from their terrestrial counterparts. The goals of this study were to investigate the following in a precocial obligate swimmer: (1) variation of mechanical properties among regions of the vertebral column and ontogenetic development and (2) relationships between vertebral process lengths and mechanical properties of bone tested in the orientation parallel to each process. We investigated bone behavior in the Florida manatee (*Trichechus manatus latirostris*) at various regions along the vertebral column. Vertebrae were dissected and machined into three orientations for compressive tests and stiffness, yield strength, and toughness were calculated from stress-strain curves. We found significant variation among column regions and age groups. Perinatal bone properties were statistically consistent among column regions. Adult bone was the most resilient and strong in posterior regions but stiffest in anterior regions. Calf bone properties were similar to perinatals in the anterior regions, but matched the older age groups in posterior regions, suggesting that caudal vertebral bone ossifies first in manatee development to support undulatory locomotion. Transverse process lengths had moderate positive correlations with mediolaterally tested bone for all properties, potentially providing greater bone surface area for muscle attachment and increasing force production on vertebrae.

120-5 INJAIAN, AS*; TAFF, CC; PEARSON, KL; GIN, MMY; PATRICELLI, GL; VITOUSEK, MN; Cornell University, Cornell University , University of California, Davis, University of California, Davis; *alinjaian@gmail.com*

Effects of experimental chronic traffic noise exposure on adult and nestling corticosterone levels, and nestling body condition in a free-living bird

Alterations in the acoustic landscapes due to human disturbance are likely to be pervasive and persistent (i.e. chronic). It is important to understand if chronic noise exposure alters behavior and physiology in free-living animals, as it may result in long-lasting impacts, such as reduced reproductive success. Here, we experimentally tested the effects of chronic traffic noise on baseline and stress-induced corticosterone (the primary avian glucocorticoid), parental feeding behavior, and fitness proxies in breeding tree swallows. Our results show that chronic traffic noise is related to altered corticosterone in both adult female and nestling tree swallows, suggesting that noise may be a stressor in both groups. In adult females, our results suggest that traffic noise is related to a limited ability to respond to subsequent acute stressors (i.e. reduced stress-induced corticosterone levels after handling). Further, our results show no evidence of habituation to noise during the breeding season, as the negative relationship between traffic noise and adult female stress-induced corticosterone became stronger over time. In nestlings, we found a positive relationship between traffic noise exposure and baseline corticosterone. Finally, we found a negative relationship between traffic noise and nestling body condition, despite no detectable effects of noise on nestling provisioning (e.g. parental feeding rate, or insect bolus size/composition). These results highlight the potential long-term consequences of chronic noise exposure.

P1-148 IRWIN, SJ*; SANGER, TJ; JOHNSON, MA; Trinity University, San Antonio, Loyola University, Chicago, Trinity University, San Antonio ; *sirwin@trinity.edu*

Social and Exploratory Behaviors Of Thermally-Stressed Lizard Hatchlings

The temperature at which vertebrate eggs are incubated can significantly alter the phenotype and behavior of the juveniles. More specifically, increases in incubation temperature as small as a few degrees can result in malformations of the skull and changes in brain morphology. This pattern has been observed in multiple vertebrate species. While previous studies have shown that aspects of cognition are altered by differences in incubation temperature, especially in ectotherms, we do not yet know how temperature-related changes in morphology may be associated with animal social behavior. In this study, we performed a series of behavioral trials on *Anolis sagrei* (the Cuban brown anole) hatchlings from eggs incubated at standard (27° C) and elevated (34° C) temperatures to determine how incubation temperature affects interactions with conspecifics, predators, and prey. We also measured the extent to which these lizards explore novel objects and novel environments. Our data suggest that hatchlings exposed to embryonic heat stress are both less exploratory and less aggressive than hatchlings from eggs incubated at standard temperatures. By quantifying how changes in the thermal environment of embryos are associated with post-hatching behaviors, we contribute to a growing understanding of how embryonic heat stress may impact the ecology of animals in a warming world.

42-1 ISAACS, MR*; LEE, DV; University of Nevada, Las Vegas; *michael.isaacs@unlv.edu*

Mechanical Cost Dynamics of Single and Double Stance in Human Walking

Conventionally, all or nearly all of the mechanical cost of bipedal walking is assumed to be incurred during the step-to-step transition, whereas the single stance or 'vaulting' phase is assumed to be free of cost. We investigate human walking dynamics using mechanical cost analysis (MCA) to analyze single stance (SS) and double stance (DS) periods of the stride separately. This strategy determines the contribution of SS and DS dynamics to the mechanical cost of transport (CoT_{mech}) for a single stride. We test the effect of walking speed on SS and DS mechanical cost dynamics in nine healthy adults. Our experimental results show collision angles of 0.07 in DS and 0.05 radians in SS, indicating that the dynamics of DS are more costly than those of SS. As walking speed increases, collision angles remain relatively constant, force angles increase in both DS and SS, and velocity angles increase in SS and decrease in DS. Increasing force angles are consistent with greater step lengths during faster walking. Velocity angles increase by 22% in SS, due to longer steps, but decrease by 31% in DS as walking speed increases. Decreasing velocity angles during DS indicate that redirection of the CoM from down to up happens more quickly and has a flatter trajectory as walking speed increases. Collision angles, and thus CoT_{mech}, remain relatively constant across the speed range considered. With increased walking speed, the collision fraction - a ratio of the actual collisions to the potential collisions - remains relatively constant during DS, but this fraction is reduced by 24% during SS. This means that the dynamics of the step-to-step transition remain similar, regardless of speed. In contrast, collisions are mitigated more effectively during SS at faster walking speeds. A key finding of this work is that mechanical cost is not relegated to just the step-to-step transition.

P1-86 IVANINA, AV*; SOKOLOVA, IM; University of North Carolina at Charlotte, Charlotte, NC, USA , Department of Marine Biology, University of Rostock, Rostock, Germany; *aivanina@uncc.edu*

Effects of salinity on cellular energy budget of biomineralizing tissues of marine bivalves

Shell provides mechanical support and protection from predators and environmental stressors. The mantle edge (ME) and hemocytes (HCs) play a major role in molluscan shell formation, and this process is an energetically demanding. The aim of this study was to determine whether energy costs of biomineralization increase under the conditions unfavorable for $CaCO_3$ deposition and if so, which cellular functions might be responsible for that. Two species with different shell mineralogy (*Crassostrea gigas* and *Mercenaria mercenaria*) were exposed for 2 weeks to 3 salinities (30, 18 or 10) and cellular energy demand for protein synthesis, bicarbonate turnover, Ca^{2+} transport, and H^+ transport was measured in ME cells and HCs. In clams' ME, the energy demand was similar for the 4 studied cellular processes. Acclimation of clams to 10 PSU led to allocation of energy into the protein synthesis and bicarbonate production. The energy allocation of the oysters' ME and HCs into the 4 studied cellular processes was balanced at salinity 30 PSU, whereas at 18 PSU an energy flux was diverted to the protein synthesis and H^+ transport. Acclimation to 10 PSU led to major decrease of energy demand for all 4 cellular processes in oyster HCs. In the oysters' ME energy allocation into the studied cellular processes at 10 PSU was similar to that at 30 PSU. Our data indicate that energy cost of biomineralization in M. mercenaria and C.gigas have different sensitivity to low salinity. In oysters, the energy costs of biomineralization-related functions of HCs and ME cells were highly affected by lowest salinity, where in clams the energy costs for biomineralization were robust to all tested experimental conditions.

1-1 IWANIUK, AN*; O'NEIL, NP; DEAUX, E; CHARRIER, I; Univ. of Lethbridge, Canada, Univ. Paris-Sud, France, Univ. Paris-Sud, France; *andrew.iwaniuk@uleth.ca*

Individual and Seasonal Variation in the Courtship Display of Ruffed Grouse.

The performance of courtship displays varies greatly among and within individuals of a species. Within individuals, displays can vary in quantity and quality throughout a bout, day or season and some individuals are faster, more coordinated or more consistent than others. Intra- and inter-individual variation in birdsong has been studied heavily, but comparable studies of non-vocal courtship displays in birds remain relatively rare. Over the past 9 years, we have studied courtship in ruffed grouse (*Bonasa umbellus*), a gamebird species that produces a wingbeating display known as drumming. Here, we test whether males vary their drumming display within a season and to what extent that variation reflects body size. Generalized additive mixed models revealed that male ruffed grouse increase their drumming speed daily to reach a maximum rate by mid-morning, which is then maintained throughout the day. This change in performance follows an overnight cessation of activity and low temperatures, suggesting that this increase in drumming speed reflects a daily warm-up period. Comparisons with morphometric measurements revealed that the maximum daily drumming speed varies inversely with body mass; larger males drum slower than smaller males. This inverse relationship is likely due in part to pectoral muscle mass, which comprises one third of male body mass and varies seasonally in association with drumming activity. Based on our findings, we propose that warm-up periods are a common feature of avian courtship displays and further studies are needed across species that vary in the diversity of motor acts that are produced within displays.

P3-153 IYENGAR, EV; Muhlenberg College; *iyengar@muhlenberg.edu*
As the world warms: Hydration status of a native (Ariolimax columbianus) and invasive (Arion rufus) slug in the temperate rainforest
The recent pattern of replacement of populations of the native banana slug (*Ariolimax columbianus*) by the invasive terrestrial slug *Arion rufus* on San Juan Island, Washington state, USA, may be due to differences in susceptibility to desiccation rather than direct competition. While both species are poikilotherms, the native species is endemic, so it is likely even more sensitive to environmental changes. Recent years have been aberrantly hot and less humid. Field collections examining the level of hydration of different subpopulations of these two species indicated some small differences. However, in general both the hydration levels and the evaporation response of the two species of slugs to maintenance at different temperatures was surprisingly similar, and elevating maintenance temperature by 10oC did not necessarily increase the amount of evaporation. Therefore, it appears unlikely that physiological differences in susceptibility to desiccation are the main factors driving the recent differences in population dynamics. Alternative hypotheses, such as competition for food or shelter, should be investigated.

49-1 JACKSON, KM*; MOORE, PA; Bowling Green State University, OH; *kelmjac@bgsu.edu*
The Effects of Artificial Light at Night: Behavioral and Physiological Shifts within Two Crayfish Species, Faxonius rusticus and Faxonius virilis
A significant amount research exploring the impacts of light pollution and artificial lighting at night has focused on vertebrates. The lack of literature on invertebrate species, especially aquatic invertebrates, is an important gap in knowledge. Aquatic invertebrates are often keystone species; thus, any changes within the organisms themselves can severely affect entire ecosystems. We investigated how properties light at night had altered the physiology and behavior within two different aquatic invertebrates, the virile crayfish (*Faxonius virilis*) and rusty crayfish (*Faxonius rusticus*). Data was collected for ten weeks at the University of Michigan Biological Station (UMBS) in Pellston, MI. Behavioral data was measured as the overall time spent consuming food, hiding in shelters, as well as the amount, duration, and intensity of agonistic interactions. Hemolymph was obtained to quantify the stress levels within the crayfish as a physiological response. Exposure to a higher intensity of light and the presence of ultraviolet light induced a behavioral trend, resulting in lower amounts of social interactions within both species of crayfish. Due to the importance of freshwater ecosystems and the role crayfish play as a keystone species, examining how crayfish are impacted from ecological light pollution is imperative to maintaining the health of aquatic ecosystems.

P1-213 JACKSON, JL*; SLOAT, SA; ROCKMAN, MV; New York University; *mrockman@nyu.edu*
Caenorhabditis nematode diversity in a neotropical rainforest
Caenorhabditis nematodes are abundant, globally distributed animals. Although *C. elegans* is one of the best studied organisms in biology, basic features of *Caenorhabditis* biodiversity and biogeography are poorly characterized. We isolated nematodes from more than 300 substrates (rotting fruit and flowers) collected on Barro Colorado Island, Panama, to discover the baseline characteristics of the local *Caenorhabditis* fauna. We identified *Caenorhabditis* worms morphologically and performed experimental mating tests with known strains in the laboratory to determine species identities. The majority of isolates were *C. briggsae* and *C. tropicalis,* two species with androdioecious mating systems (males and hermaphrodites). These two species are globally distributed. The remaining isolates belong to three species of *Caenorhabditis* with gonochoristic mating systems (males and females). Two of these, *C. becei* and *C. panamensis,* are known only from Panama. Species were not restricted to particular substrate types. Our results are consistent with emerging patterns in *Caenorhabditis* biogeography, which show that androdioecious species are cosmopolitan while gonochoristic species often have narrow geographic distributions.

P1-254 JACOB, S*; BENNETT, S; Mount Holyoke College, California Academy of Sciences; *jacob25s@mtholyoke.edu*
Dengue, Zika, and Chik, oh my! The evolution of Dengue virus in Nicaragua
Dengue virus threatens almost half of the world's population and is an endemic in more than 100 countries. *Aedes aegypti* (yellow fever mosquito), carries and transmits dengue in Nicaragua, and began transmitting Zika and chikungunya in 2015 and 2013 respectively. Dengue dates back nearly 2000 years in humans, yet has recently increased in distribution and severity, establishing in Nicaragua in the 1970s. Dengue's global expansion and increasing disease impact is due to three factors: urbanization, virus evolution, and the evolution and spread of mosquito vectors. The viruses' short generation time, large population sizes, and high mutation rates contribute to their rapid evolution. We sought to understand how dengue virus has evolved in Nicaragua during its emergence there, and following the introductions of Zika and chikungunya. Using second-generation sequencing, we characterized whole-virus genomes from virus-positive Nicaraguans collected between 2013 and 2016, by extracting whole-genome viral RNA, developing molecular libraries that were then pooled and run on the Illumina MiSeq. Cleaned and assembled genomes were identified with BLAST and aligned with virus genomes from the region over a similar timespan downloaded from publicly available databases. Comparing these sequences with maximum-likelihood phylogenetics showed that dengue viruses in Nicaragua are under different forces of evolution: dengue serotype 1 is marked by two distinct co-circulating forms; dengue 2 disappeared near the time that chikungunya arrived but has since resurged with a distinct lineage that may have evolved in situ and under adaptive evolution; dengue 3 has been dominant in recent times but has little phylogenetic structure. In general, population estimates of dengue seem to show a decline when chikungunya and Zika first arrived, but are now resurging.

P3-104 JACOBS, F*; AHEARN, GA; University of North Florida; *mariaflorajacobs1@gmail.com*

Effects of aquatic acidification on ^{45}Ca uptake by gill epithelia of white river shrimp Litopenaeus setiferus

Previous research regarding the effects of aquatic acidification on invertebrate calcium carbonate skeletons suggested that protonation of carbonate was largely responsible for skeletal dissolution. In seawater, calcium has not been considered a limiting factor. This study suggests that pH may affect the uptake of calcium in freshwater river shrimp (*Litopenaeus setiferus*) gills, potentially limiting calcification processes. This project describes ion transport mechanisms present in cell membranes of river shrimp gill epithelia, and the effects of pH on the uptake of ^{45}Ca by these cells. Partially purified membrane vesicles (PPMV) of shrimp gills were prepared through a homogenization/centrifugation process that has been used previously to define ion transport in crab and lobster gill tissues. In the current study, shrimp gill PPMV ^{45}Ca uptake at 15µM, 50µM, and 250µM was highest at pH 7.0 and lowest at pH 6.0. A valinomycin/K^+ induced membrane potential (PD) across vesicle membranes at pH 7.0 significantly increased ($p=0.008$) ^{45}Ca uptake from that observed in the absence of a PD at pH 7.0. An induced PD at pH 8.0 also significantly increased ($p=0.033$) ^{45}Ca uptake from that observed in the absence of a PD at pH 8.0, however the uptake at pH 8.0 in the presence of a PD was significantly less than that at pH 7.0 in the presence of a PD ($p=0.013$). The cation antiporter inhibitor amiloride (2 mM) partially blocked ^{45}Ca uptake at pH 7.0, while the cation channel inhibitor verapamil (100 µM) was without effect. Results suggest that river shrimp gills transport ^{45}Ca by way of an electrogenic carrier that likely displays a Ca^{2+}/H^+ transport stoichiometry and is affected by external pH.

129-5 JACOBS, C*; DAY, S; HOLZMAN, R; Tel Aviv University, Rochester Institute of Technology; *corrinej2@gmail.com*

The Power of Pivot Feeding: A Neglected Role For Power Amplification in Syngnathidae.

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 in the Syngnathidae family, whose members are able to rotate their snout towards the prey at exceptionally high speeds of ~1.56 ms^{-1}. While the mechanism of power amplification that permits these exceptional speeds is well documented, the consequences of power amplification for suction feeding are poorly understood. Specifically, there have been no studies documenting the magnitude or spatio-temporal patterns in the suction flows produced using power amplification. 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 Syngnathidae family. We found that the power amplification provides 8x greater flow velocities, compared to fish with no such mechanism. Both between and within species, shorter snout lengths were correlated with faster flow speeds. Peak flow speeds occurred early in the gape cycle (~60% of time to peak gape), and mid-way through head rotation. We used the observed flow fields to estimate the pressure fields in front of the mouth and calculate net suction power (power used to accelerate the water outside of the mouth) in both power amplified and non-amplified fish species. We further compare the net suction power to the power required for head rotation in our species. Our results reveal a neglected role for power amplification in Syngnathidae.

P2-245 JACQUEMETTON, CP*; BIRD, DJ; VAN VALKENBURGH, B; University of California, Los Angeles; *cjacquem@ucla.edu*

Cribriform plate shape in domestic dogs is heavily influenced by cranial shape

The relationship between humans and domestic dogs has dramatically changed in the ~20,000 years since their domestication. In the past 500 years, domestic dogs have increasingly become the focus of intense artificial selection, leading to extreme variation in skull shape. Selection for snout length has been particularly intense, with some dogs having long slender snouts (many sighthounds), and others having almost no snout at all (pugs). This likely has impacts on structures within the snout, such as those related to olfactory ability including the cribriform plate. Using CT scans from over 40 dog breeds, we reconstructed the cribriform plate using Materialise 3-D rendering software and then applied geometric morphometrics to quantify how cribriform plate shape varies among breeds. The overall shape of the cribriform plate across domestic dogs varies greatly, and closely maps the overall shape of the snout. In dog breeds with thin elongate snouts, the cribriform plate is long and narrow, much like a vase, whereas in dogs with shortened snouts, the cribriform plate resembles more of a shallow, broad dish. While dog breeders have not selected for alterations to the shape of the cribriform plate, the intense selection for extreme skull shapes in a relatively short period of time has greatly modified the shape of the cribriform plate.

9-4 JAHAN, I; MAIA, A*; Eastern Illinois University, Rhode Island College; *aresendedamaia@ric.edu*

Temperature affects in vivo muscle mechanics in swimming Centrarchids

In vitro studies have shown that temperature can directly affect muscle mechanics. However, as climate changes, it is increasingly important to see how ectotherms physiology is impacted. Here we investigate in vivo muscle mechanics under varying water temperatures during steady swimming in largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*). Fish were collected in central Illinois streams and housed at 20°C until tested in a recirculating flow tank swimming steadily at 2 body length (BL)/sec at three different temperatures: 16°C, 20°C and 22°C. To perform intramuscular electromyography, bipolar electrodes were inserted through the skin into epaxial white muscle at below the dorsal fin (axial, 0.5BL) and epaxial red muscle both below the dorsal fin (axial, 0.5BL) and closer to the tail (caudal, 0.75BL). Electromyographic recordings were analyzed for magnitude, frequency, onset, offset, duration and duty cycle. We found that in largemouth bass white muscle suffers a phase shift with increased temperature and is recruited concurrently with red muscle. At higher temperatures, bass also have greater contraction magnitude in both white axial and red caudal muscles, but not in axial red muscle; while contraction frequency decreases. In contrast, the main differences in in vivo muscle mechanics in bluegill were increased duty cycles of caudal and axial red muscles at higher temperatures, although caudal red muscle appears to contribute the most to power output. This study reveals that in vivo muscle mechanics in centrarchids are altered with changes in water temperature. In bass, additional recruitment of white muscle at higher temperatures can lead to early fatigue and have strong metabolic impacts. Bluegill appear to use a different strategy by altering the contraction dynamics of red muscle, which can directly increase energy expenditure.

P3-156 JAMAL, FA*; KOWALEWSKI , MJ; PAULAY, G; University of Florida; *fjamal@ufl.edu*

Pinnotherid Crabs and Their Sand Dollar Hosts, Eastern Gulf of Mexico

The genera *Dissodactylus* and *Clypeasterophilus* (Family: Pinnotheridae, Phylum Arthropoda) are commensal or parasitic crabs that live in association with irregular sea urchins (Class Echinoidea, Phylum Echinodermata). The association of pinnotherid crabs on sand dollars was studied off of Steinhatchee, FL, in the eastern part of Gulf of Mexico during 2017 and 2018. A total of 18 sites were sampled by scuba, including repeated sampling of 2 sites. Each sand dollar along with its crabs was collected in a separate Ziploc bag while scuba diving. Sand dollars were identified to species level and body size was estimated in terms of maximum body length and body width. Morphological and molecular approaches were employed to identify species of crabs. The number of crabs found on each sand dollar, maximum carapace width, maximum carapace length and sex were also noted. A total of 606 echinoids hosting 1322 crabs were collected. The analytical results indicate that three molecularly distinct pinnotherid crab species (*Clypeasterophilus stebbingi*, *Dissodactylus latus*, *Dissodactylus mellitae*) were associated with five species of sand dollars. Distribution of crabs suggests host species preference. In contrast, pea crabs infested echinoid hosts across a wide range of size classes. Collectively, the mean burden (number of crabs per sand dollar) was 2.18 (including uninfested hosts), with individual burden varying from zero to sixteen crabs per host specimen. Male to female sex ratio was 1.16:1. Some sand dollars were heavily infested (59.74%-96.6%) and *Mellita tenuis* being the least infested host (37.3%).

28-1 JAMES, E*; FENG, H; LU, H; WILSON, A; University of Miami, MingDao University; *ebj26@miami.edu*

The role of mTOR at a symbiotic interface

Obligate nutritional endosymbioses represent the most intimate relationship between species. Nutritional endosymbioses are well studied, but we lack a full picture of how two disparate organisms, a bacterial endosymbiont and a eukaryotic host, are integrated. The mTOR pathway is known to integrate nutritional conditions with cell growth and survival. Recent work on amino acid transporters in aphids suggests the mTOR pathway as point of integration between an aphid host and it's amino acid provisioning endosymbiont *Buchnera aphidicola* (housed in specialized organs called bacteriomes). The mTOR pathway was previously unstudied in any nutritional endosymbiosis. We annotated the mTOR pathway in two aphid species, *Acyrthosiphon pisum* and *Myzus persicae* using BLASTp from *Drosophila melanogaster*, HMMs, and gene phylogenies. We constructed transcriptomes for bacteriome, gut, and whole insect tissue for three lines of *M. persicae* and carried out differential expression analysis. Annotation of the mTOR pathway identified some novel duplications in both aphid species. Differential expression analysis showed that genes specific to the amino acid sensitive mTOR Complex 1 were more highly expressed in bacteriomes than genes specific to mTOR Complex 2. In comparison to gut, another nutrient-provisioning tissue, the putative glutamine/arginine sensing transporter SLC38A9 showed 6.5 fold higher bacteriome expression. Characterization and immunolocalization of the SLC38A9 is underway both to confirm orthology, and interrogate its role in a new symbiotic context. This exploratory study suggests that the mTOR pathway may play an important role in mediating the relationship between aphids and their endosymbiont *Buchnera*. Our work especially highlights the need for more intensive study of the mTOR pathway in nutritional endosymbiosis

113-8 JAMES, DM*; KOZOL, RK; KAJIWARA, Y; WAHL, AL; STORRS, EC; BUXBAUM, JD; KLEIN, M; MOSHIREE, B; DALLMAN, JE; University of Miami, Icahn School of Medicine at Mount Sinai, Icahn School of Medicine at Mount Sinai, University of North Carolina ; *david.james@bio.miami.edu*

A shank3 Loss-of-Function Model of Autism Spectrum Disease (ASD) Produces Intestinal Dysmotility and Reduced Serotonin Positive Enteroendocrine Cells

Autism Spectrum Disorder (ASD) is currently estimated to affect more than 1% of the world population. While behavioral deficits and symptoms such as epilepsy are well studied, gastrointestinal (GI) distress remains a commonly reported but poorly understood comorbidity. Recent advances in gene editing techniques have allowed us to capitalize on the genetic aspect of ASD; to determine mechanisms behind ASD related GI distress, we explore how mutations in genes with high autism relatedness impact GI function. Mutations in the high-confidence ASD gene SHANK3 are considered causal for Phelan-McDermid Syndrome (PMS), a form of ASD with associated GI distress. Using the zebrafish as a model system, we used CRISPR/Cas9 to introduce clinically relevant C-terminal frameshift mutations in *shank3a* and *shank3b* zebrafish paralogues. We found that these mutations produce significantly slower rates of peristaltic contractions with correspondingly prolonged digestive passage time. Rescue injections of mRNA encoding the longest human SHANK3 isoform into *shank3* zebrafish mutants produced larvae with gastric emptying similar to WT, but with remaining deficits in posterior intestinal motility. Serotonin-positive enteroendocrine cells were significantly reduced in *shank3* mutants while enteric neuron counts and overall structure of the digestive tract epithelium, including goblet cell number was unaffected in shank3 mutant larvae. By contrast, in adult *shank3* mutants there was a significant increase in goblet cell counts, suggesting a possible secondary inflammation that progresses with time

24-6 JANIS, B*; JANIS, S; YAVUZCETIN, O; SOLOCINSK, J; CHAKRABORTY, N; MENZE, MA; University of Louisville, University of Wisconsin-Whitewater, University of Michigan-Dearborn; *Brett.Janis@Louisville.edu*

Liquid-Liquid Phase Separation Behavior of a Crustacean Late Embryogenesis Abundant Protein

Late Embryogenesis Abundant (LEA) proteins are a remarkable group of intrinsically disordered proteins (IDPs) that confer desiccation tolerance to plants and animals that can enter a cryptobiotic state during their life cycle. *Afr*LEA6 contains seed maturation domains (SMD) and is expressed in the anhydrobiotic cysts of the brine shrimp *Artemia franciscana*. *in vitro* analyses of *Afr*LEA6 reveal a series of protein phase transitions during desiccation. As ionic strength or molecular crowding with Ficoll-400 increases, *Afr*LEA6 undergoes a liquid-liquid phase separation (LLPS), forming protein droplets. *Afr*LEA6 droplets are also inducible by reducing the sample pH from 8.0 to 6.5 and cooling protein solutions from 25˚C to 4˚C. These conditions are notable in the context of the cysts of *A. franciscana*, which can naturally undergo a cytoplasmic pH shift from 7.9 to 6.5 in response to severe hypoxia. In the hydrated state, *Afr*LEA6 droplets exclude green fluorescent protein demonstrating that the protein droplet may be selective for inclusions of specific targets. SEM and AFM reveal that *Afr*LEA6 may also undergoes a phase shift to a hydrogel structure, as ionic strength and crowding increase, which is reversible upon rehydration. However, early during dehydration formed hydrogels dry into a reversible glassy state during complete desiccation. The LLPS of *Afr*LEA6 may confer desiccation tolerance by selectively incorporating sensitive protein targets and shielding them from desiccation induced denaturation during early drying. Any incorporated proteins may then be stabilized within a glassy compartment in the fully desiccated state and released upon rehydration (supported by NSF IOS-1659970).

42-5 JANKAUSKI, MA; Montana State University;
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Experimental Studies of Power, Moments and Energetics in Flapping, Flexible Insect Wings
Flapping insect wings bend and deform during flight. Recent evidence suggests this deformation improves power economy and reduces the cost of locomotion. To assess this hypothesis, we drive a hawkmoth *M. Sexta* wing with single degree-of-freedom rotation using a DC motor and calculate the corresponding mechanical power requirements. We consider a 60-degree rotation amplitude and a wide range of flapping frequencies. Wing moments are measured via a custom torque transducer and the flap angle is measured using an optical encoder. The two measurements are utilized to estimate the mechanical power required to flap the wing. Experiments are conducted in-air and in-vacuo to provide insight into inertial-elastic and aerodynamic energetics. Our results suggest that at a typical flap frequency of 25 Hz, the wing requires maximally 40 mW in-air and 30 mW in-vacuo. Peak moments corresponding to these power draws are 0.55 mN-m and 0.35 mN-m, respectively. We estimate that for the in-vacuo case, the real flexible wing requires only 75% the peak power relative to an idealized rigid wing. Next, we identify the root-mean-square (RMS) value of mechanical power as a function of flapping frequency, where the RMS value of power is a proxy for total energy expenditures. We find that over the entire 15-30 Hz flap frequency range, the RMS mechanical power of the wing is higher in-air than in-vacuo. Furthermore, we observe that for the in-air response, the RMS power follows a non-monotonic trend, where it decreases temporarily as the flapping frequency is increased beyond 1/3 of the wing's second natural frequency. Thus, it is plausible that tuned structural compliance may facilitate the energy efficiency of flapping insect wings.

94-4 JANZEN, FJ*; DELANEY, DM; MITCHELL, TS; WARNER, DA; Iowa State University, University of Minnesota, Auburn University; *fjanzen@iastate.edu*
Do Covariances between Maternal Oviposition Behavior and Embryonic Physiology Drive Sex-Ratio Evolution under Environmental Sex Determination?
Fisherian sex-ratio theory predicts sexual species should have a balanced primary sex ratio. However, organisms with environmental sex determination are vulnerable to excessively skewed sex ratios when environmental conditions vary. Theory has emphasized two traits important for sex-ratio dynamics in animals with these mechanisms: (1) maternal oviposition-site choice and (2) sensitivity of embryonic sex determination to environmental conditions. Much research has since focused on how these traits influence offspring sex ratios. Still, relatively few studies have estimated univariate quantitative genetic parameters for these two traits, and the existence of phenotypic or genetic covariances among these traits has never been assessed. Here, we leverage work on three species of reptiles (two divergent turtle species and a lizard) with temperature-dependent sex determination (TSD). These studies measured maternal behaviors that relate to nest temperature under field conditions and assessed the corresponding sex ratio of offspring from eggs incubated under controlled temperatures. A strong concordant covariance between these traits would maximize the efficiency of sex-ratio selection. We detected no such covariance between nest-site choice and thermal sensitivity of sex determination in the three species studied. Consequently, our results suggest these traits are able to evolve independently. Even so, a comprehensive review of the existing literature on quantitative genetic estimates for traits related to TSD identifies minimal microevolutionary capacity in the wild, in most cases. Such information is critical for understanding how animals with TSD might respond to rapidly changing environmental conditions.

P2-5 JARAMILLO, AM*; KOVAL, MK; RODRIGUEZ, KM; SANCHEZ, AM; DUNN, SR; DER, JP; BURNAFORD, JL; California State University Fullerton;
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Stayin' Alive? Assessing the ability of an intertidal seaweed to recover from repeated exposure to desiccation and high temperatures during low tide
Silvetia compressa, a canopy-forming alga, plays a vital role in rocky intertidal ecosystems as a primary producer and habitat for animals. Intertidal organisms are under seawater at high tide and exposed to terrestrial conditions at low tide. Stressors such as wind and heat during low tide can negatively affect algal physiology and subsequently biomass and canopy cover. We manipulated hydration level (values down to 17% wet mass) and body temperature (low mean = 22.79ºC, high mean = 30.49ºC) over two simulated low light low tides, and monitored the effect on biomass and maximum quantum yield (MQY: a measure of photosynthetic potential) over three days of recovery in simulated high tide conditions. At the end of the second low tide, hydration status was positively correlated with MQY in both low ($r = 0.92$) and high ($r = 0.94$) temperature treatments. Following 84 hours of recovery, biomass loss was minimal and not strongly associated with low tide temperature or desiccation and negative effects of desiccation on MQY disappeared, but on average, MQY in high temperature treatments was only 91.6% of that in low temperature treatments. Temporary MQY decreases following low tide desiccation indicate a reduced ability to produce sugar which could affect growth. Repeated exposure to warm low tides could slowly lower an individual's maximum attainable photosynthetic potential. The combination of dry and warm days could ultimately lead to a decrease in canopy cover, exposing understory organisms to harsh low tide conditions with long term effects on community structure and function.

P1-73 JASINSKI, SE; State Museum of Pennsylvania;
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Emydid turtles from the Miocene-Pliocene of the southern Appalachian Mountains and their implications for the evolution of the Emydidae
Emydid turtles (Testudines: Emydidae) are the most diverse and widespread family of turtles in the New World today. The fossil record of emydids is made up mostly of fragmentary remains from several main fossil regions, including Florida, Nebraska, and Kansas. Today the family consists of 10 to 12 extant genera and over 50 species. While the fossil record has a relatively high amount of disparity, many of the fossil taxa are fragmentary and have later been synonymized with other taxa, reinterpreted as being members of other families, or considered nomina dubia. The Gray Fossil Site, in eastern Tennessee, is a fossil locality interpreted as an ancient pond-like sinkhole from the latest Miocene-early Pliocene. The site has at least four fossil emydids including representatives of *Trachemys*, *Chrysemys*, *Terrapene*, and *Emydoidea*/*Emys*. All these turtles represent distinct species. Based on phylogenetic analyses, they show similarities with species from various geographic regions, suggesting these represent a non-analog turtle fauna. *Trachemys haugrudi* from the site is found to be closely related to fossil species from Florida. The new species of *Chrysemys* is most closely related to fossil *Chrysemys* from Nebraska, although the latter is Pleistocene in age. A new species of *Terrapene* lies outside crown *Terrapene* and near the base of the *Terrapene* clade while also being most closely related to species from the midwestern United States. The fourth, enigmatic emydid shows affinities with *Emydoidea* and *Emys*. If a member of the former genus, it would represent the southern-most extent of *Emydoidea*, modern or fossil, whose modern biogeographic range extends to central Indiana. The distinct turtle fauna at the Gray Fossil Site provides significant new information in our understanding the evolution of the emydids.

111-1 JAUMANN, S*; SMITH, A; George Washington University; *sjaumann@gwu.edu*

Effects of Experience on Brain Development in a Facultatively Social Bee

Social animals face unique selection pressures, including selection on brain development. In some bees, the brains of social queens, social workers, and solitary individuals are morphologically distinct. The mushroom bodies are the brain regions in insects responsible for higher-order processing, and these tend to be relatively larger in older bees compared to newly-emerged bees and larger in social bees compared to their solitary counterparts. That mushroom bodies are plastic over time suggests that the brain differences between solitary and social bees develop over the adult lifetime of the bees, but whether these changes are due to age or experience is not known. We tested the hypothesis that adult experience alters brain morphology in the facultatively social sweat bee *Megalopta genalis*. We collected four groups of bees: newly-emerged bees with no experience, bees that had experience with their mothers and searching for nest sites, bees that lacked these experiences but were placed in observation nests that mimicked natural nests, and bees that were isolated for ten days, completely lacking any natural experience. Using confocal microscopy, we measured total brain volume and relative mushroom body volume on the brains of bees from these four groups. Our analyses suggest that there were not significant differences in total brain volume among the four groups, but that there were significant differences in relative mushroom body volume. However, no clear pattern emerged, as newly-emerged bees and bees from observation nests had higher relative mushroom body volumes than bees in the other groups. A follow-up study will determine if changes in the brain across development show the same pattern in solitary and social bees, given that differences between a solitary and social developmental trajectory might help explain our results.

P1-44 JAVIER, JP*; PAIG-TRAN, EWM; California State University, Fullerton; *jpjavier@csu.fullerton.edu*

Filtration Along a Reticulated Mesh, Anatomy Predicts Feeding Ecology in Neonatal Whale Sharks, Rhincodon typus

The largest fish in the ocean, *Rhincodon typus* (Whale Shark), is one of three filter-feeding sharks. While a few studies have predicted the filtration mechanism used by *R. typus*, none of these studies have successfully verified this mechanism in either a live or model animal. In addition, no studies have predicted the prey selectivity in a neonatal whale shark. The objective of this study was to explore how the morphology of the filter pad separates food particles from the water. We documented the filter anatomy in neonatal whale shark specimens and calculated the freestream and transverse flow through the buccal cavity and filter pores respectively. We then created anatomically correct, scaled 3D physical models of the filter pad reticulated mesh and inserted the printed filters into a physical model of a whale shark buccal cavity. We ran a series of filtration experiments using microspheres (60 µm - 340 µm) that represent the full-size range of potential zooplankton prey. Modeling the neonatal specimen allows us the rare opportunity to study feeding mechanisms in an animal that is CITES protected and rare in aquaria. Understanding the mechanism of filtration and prey selectivity in neonatal whale sharks helps to predict their ecology and likely habitat usage in the wild.

81-3 JAYARAM, K*; DOSHI, N; WOOD, R; Harvard University; *kjayaram@seas.harvard.edu*

Gait recovery using proprioceptive feedback in HAMR, a biologically-inspired robotic platform

Animals rely on local sensory feedback to maintain a variety of complex leg/foot trajectories when navigating natural terrains. The choice of trajectory is determined by a combination of factors including to body morphology, actuation capabilities, performance requirements, and environment. In contrast, a majority of bioinspired legged robots today are typically restricted to utilizing one (or few) pre-programmed leg motions during running due to the complexity of leg design, difficulty in actuation, and a lack of reliable sensing resulting. To address this issue, we present the latest generation of the Harvard Ambulatory MicroRobot (HAMR) - an insect scale (45 mm long, 1.43 g) quadrapedal robot that retains mechanical complexity despite its small size. HAMR is capable of high-speed locomotion on level ground, can climb vertical and inverted walls, and even swim on the water's surface. In order to test the hypothesis about leg trajectories affecting locomotion performance, we have developed and integrated a novel motion encoder that provides a reliable estimate of the robot's joint position and velocities. We then utilize this proprioceptive feedback to control heuristically designed leg trajectories and demonstrate that we can recover locomotion performance (stride length) in highly dynamic frequency regimes (10-30 Hz). Additionally, at higher frequencies (40-50 Hz), we observe that the shape of leg trajectories is less important if the energy exchange between the robot and terrain is appropriately modulated. With precise control over arbitrary leg trajectories, we can now begin to test hypotheses about the choice of leg trajectories in biological systems at scale.

P2-27 JAYASUNDARA, N*; KOZAL, J; MASSARSKY, A; TREVISAN, R; BLUE, M; BONE, A.J.; LINDBERG , C.D.; DI GIULIO , R.T.; Univ. of Maine, ME, Duke University, NC, Univ. of North Carolina Chapel Hill, NC; *nishad.jayasundara@maine.edu*

Later-life persistent bioenergetic effects of exposure to multiple mitochondrial stressors during development in zebrafish Danio rerio

Emerging evidence suggest that mitochondrial processes and structures are reprogrammed during vertebrate development. Developmental exposure to such stressors may alter this reprogramming process leading to persistent effects on metabolism through life. We focused on zebrafish *Danio rerio* to examine synergistic later life effects of developmental exposure to a chemical (polycyclic aromatic hydrocarbons -PAHs) and physical (temperature) stressor. We focused on temperature and PAHs since thermal fluctuations are common in many aquatic habitats and PAHs are ubiquitously present at low-levels in aquatic sediments. We evaluated effects of early-life exposures to PAH mixtures on embryonic mitochondrial integrity and function at 28ºC and 32ºC, the persistent bioenergetic effects later in life at tissue and organismal level, and the role of the aryl hydrocarbon receptor (AHR) in mediating these effects. Embryo mitochondrial function was characterized using the XFe24 Extracellular Flux Analyzer. To evaluate persistent effects, mitochondrial function in whole hearts and brains of the adult zebrafish and whole organismal swimming performance and aerobic respiration were examined. Data suggest that early-life exposure to PAH mixtures results in embryonic mtDNA damage, as well as AHR-dependent changes in mitochondrial function. Interestingly, thermal exposure had no effect on embryonic mitochondrial function, but showed altered tissue bioenergetics later in life. Overall, results indicate that low-levels of developmental exposure to multiple abiotic stressors can have persistent whole organismal metabolic effects.

72-2 JAYNE, BC; BAMBERGER, AL*; Univ. Cincinnati; *bruce.jayne@uc.edu*

The Big Gulp: Morphological Determinants and Scaling Relationships of Gape in Two Invasive Species of Large Snakes

Snakes are a model system for studying gape-limited predators and how anatomy constrains and affects feeding performance and foraging. More than 3,500 extant snake species are phylogenetically diverse, consume a wide variety of prey, and have considerable ontogenetic and interspecific variation in size. However, the paucity of direct measurements of maximal gape and its morphological correlates have impeded understanding the apparent diversity of form and function of this system. To test the extent to which overall size predicted gape, we quantified the scaling relationships between maximal gape, overall size, and several cranial dimensions for a wide range of sizes for two large invasive species: 19 Burmese pythons (Henophidia, Pythonidae, *Python molorus* [Pm]) and 20 brown tree snakes (Caenophida, Colubridae, *Boiga irregularis*[Bi]). Our values of snout-vent length (SVL), mass, and maximal gape area ranged from 61-303 cm, 100-15890 g and 14-154 cm^2 for Pm, and 40-184 cm, 8-1138 g and 0.8-23 cm^2 for Bi, respectively. For similar values of SVL in common to both species (60 to 180 cm), values of Pm compared to Bi were: 6.4 to 4.2 times greater for mass, with 6.3 to 3.8 times larger for gape area, but just 1.7 to 1.6 times greater for skull length. The relative contributions to gape area from skull width, quadrate length, lower jaw length and the intermandibular ligament were 7%, 10%, 42%, and 41% for Pm, and 11%, 18%, 55%, and 17% for Bi, respectively. Rather than its large gape only resulting from larger overall size, *P. molorus* with similar body size to *B. irregularis* also had a larger skull, longer lower jaw bones and most importantly more distensible soft tissues of the chin and neck region, all of which enhanced gape.

P2-21 JEAN, G.H.Q.*; STEINWORTH, B; MARTINDALE, M. Q.; University of Miami, University of Florida, University of Florida ; *gxj52@miami.edu*

Oral-Aboral Axis Specification in "Upside Down Jellyfish" Cassiopea xamachana

Many decisions about the generation of the animal body plan, including axial patterning, are made in early development. However, many animals, such as the diverse group cnidarians, are capable of post-embryonic patterning (e.g. regeneration and asexual reproduction). Genetic networks coordinating embryonic axis specification are well-characterized in the sea anemone, *Nematostella vectensis*. In another cnidarian, *Cassiopea xamachana*, buds develop the oral-aboral axis at an angle to that of the parent polyp, presenting an interesting question of how this axis is established during asexual reproduction. Here we show a preliminary morphological and molecular analysis of *Cassiopea* embryonic development with the goal of characterizing the molecular basis of axis specification in sexual and asexual reproduction. Our results indicate that expression of certain genes with known involvement in *Nematostella* axial patterning are spatially restricted during the embryonic development, consistent with involvement of these genes in *Cassiopea* axial patterning. Differences in expression patterns between *Cassiopea* and *Nematostella* also suggest diverging roles for some of these genes. This study has progressed our understanding of embryonic axis specification and helps lay the groundwork for functional studies comparing embryonic development and asexual budding in *Cassiopea*.

P2-188 JEBB, KE*; YOUNG, CM; MORAN, CJ; GERRY, SP; Fairfield University, The Citadel; *kamryn.jebb@student.fairfield.edu*

Effects of Temperature on Muscle Physiology of Tautog

Understanding the impacts of temperature on ectotherm muscle is important for understanding thermal effects on whole organism performance. Much of the work to this point has been predicated on thermal acclimation of muscle via myosin isoform regulation. The duration of acclimation, however, has varied greatly in the literature. As a result, we aimed to address the effects of acclimation on fish locomotor muscle. By comparing thermally acclimated fish to fish taken and tested immediately from the wild we addressed the effects of acclimating fish to a specific thermal environment in the lab. Our study species was tautog (*Tautoga onitis*), a labrid fish found along the eastern coast of North America in waters that range from 5°C to 20°C. Locomotor muscle fiber kinetics and power output of the abductor superficialis muscle were measured in a group of tautog acclimated at 20°C and a group of tautog collected once water temperatures reached 20°C in the wild. Muscles were tested at 5°C, 10°C and 20°C. 20°C acclimated tautog locomotor muscle produced more power when tested at 5°C than the power produced by natural 20°C tautog when tested at 5°C. This finding suggests that increased exposure time to warmer waters allows tautog abductor superficialis muscles to perform better at colder temperatures. At colder temperatures, both 20°C acclimated and 20°C natural tautog showed a longer time to maximum twitch and time to relax when compared to that of warmer temperatures. This suggests that duration of acclimation did not impact muscle performance, rather, performance was effected by exposure to cold temperatures.

P1-34 JEFFRIES, L*; MATLOFF, L; FEO, T; LENTINK, D; Stanford Univeristy, Stanford University, Smithsonian Institution of Birds; *lindsiej@stanford.edu*

Overlapping Feathers Maintain Contact through Interlocking Microstructures during Wing Morphing

Flight feathers maintain a continuous aerodynamic surface during flight despite major wing shape changes. We have discovered that feather microstructures interact between two adjacent feathers when acted on by aerodynamic and wing extension forces. First, aerodynamic forces acting dorsal ventrally press overlapping feathers together. Then, as the bird extends its wings, a lateral extension force pulls the feathers apart. Feather separation is prevented by interlocking microstructures. To understand this microstructure interaction, we studied three pairs of overlapping pigeon, *Columba livia*, feathers. The rachises of each pair were attached to a 3D printed base with an anatomically accurate spacing. Feathers were interlocked by hand and 3D tomographic images of the interlocked regions were acquired using a Zeiss Xradia 520 Versa X-ray CT machine. Examination of the images revealed that the structures responsible for interlocking overlapping feathers appear to be hooked rami tips on the ventral side of the proximal feather's leading edge and friction barbules on the dorsal side of the distal feather's trailing edge. Comparison with SEM images of the same regions revealed that lobate cilia stick up and out of the barbule plane and may be the primary structures that interlock with the hooked rami tips. Further examination of this mechanism could be used to develop bioinspired fasteners.

S6-2 JIMENEZ, A.G.*; ANDERSON, K; O'CONNOR, E; TOBIN, K; WINWARD, J; WINNER, R; CHINCHILLI, E; AMY, M; CARLSON, K; DOWNS, C. J.; Colgate University, Hamilton College; *ajimenez@colgate.edu*

Does Oxidative Stress Differ Between Mammals and Birds?

As part of mitonuclear communication, retrograde and anterograde signalling helps maintain homeostasis under basal conditions. Basal conditions, however, vary across phylogeny. At the cell-level, some mitonuclear retrograde responses can be quantified by measuring the constitutive components of oxidative stress, the balance between RS (reactive species), and antioxidants. RS are metabolic by-products produced by the mitochondria that can damage macromolecules by structurally altering proteins and inducing mutations in DNA, among other processes. To combat accumulating damage, organisms have evolved endogenous antioxidants and can consume exogenous antioxidants to sequester RS before they cause cellular damage. RS are also considered to be regulated through a retrograde signalling cascade from the mitochondria to the nucleus. These cellular pathways have may implications at the whole-animal level as well. For example, birds have higher basal metabolic rates, higher blood glucose concentration and longer lifespans than similar sized mammals, however, the literature is divergent on whether oxidative stress is higher in birds compared with mammals. Here, we review the literature and provide new data to answer whether whole-animal metabolic phenotypic traits between birds and mammals translate into the oxidative stress machinery. Because oxidative stress has been accepted by gerontologists as the common physiological mechanism that may cause aging, has also been the process implicated in differing life-history theories, and a determinant of growth rates in animals, this work has the potential to have broad implications.

P3-112 JIMENEZ, A.G. *; ELLIOTT, K.H.; Colgate University, McGill University; *ajimenez@colgate.edu*

Measures of oxidative stress do not vary with age in thick-billed murres (Uria lomvia)

While there is growing evidence that demographic senescence is an important feature of wild populations, there remains little consensus about any physiological mechanisms that contribute to senescence in wild animals. In birds, many systems appear to remain constant with increasing age, showing no deterioration until ‘catastrophic' mortality sets in. Oxidative stress may be an important contributor to physiological senescence in wild birds because of their inherently high whole-organism metabolic rate. As a by-product of aerobic respiration, ROS (reactive oxygen species) are produced and can cause structural damage to proteins, lipids and DNA. The anti-oxidant system exists in animals to deter from rapid rates of ROS-related damage to macromolecules. As individuals age, they may accumulate oxidative damage that leads to tissue deterioration. Oxidative stress has been a debated mechanism for aging by gerontologists, ecologists and physiologists. We examined oxidative stress measurements in thick-billed murres by assessing levels of catalase (CAT), glutathione peroxidase (GPx) and superoxide dismutase (SOD) activities, and total antioxidant capacity with respect to peroxyl and hydroxyl scavenging capacity. Additionally, we measured lipid peroxidation (LPO) damage in pectoralis muscle biopsies from wild thick-billed murres aged 8 to 37 years of age (N = 41). When considered in a general linear model with body mass, body size and sex, no parameter varied with age. CAT activity increased with body size while SOD activity was higher in females. Hydroxyl scavenging capacity increased with body mass and decreased with body size. LPO damage, GPx activity and peroxyl scavenging capacity were independent of all parameters. We concluded that muscle oxidative stress levels do not vary with age in thick-billed murres, supporting the catastrophic mortality hypothesis.

129-1 JIMENEZ, YE*; BRAINERD, EL; Brown University; *yordano_jimenez@brown.edu*

Dual Function of the Epaxial Musculature of Largemouth Bass for Swimming and Suction Feeding

Swimming and suction feeding involve remarkably different motions, yet many fishes use their epaxial musculature for both. Are different regions of the musculature specialized for locomotion and feeding, or this entire muscle bifunctional? Using electromyography (EMG) on three largemouth bass, we measured electrical activity in nine regions of the epaxial musculature and identified which regions contribute to low- and high-performance swimming and suction feeding. For all feeding strikes, bass consistently activated the dorsalmost region of the epaxial muscle—the dorsal pointing arm (DPA). Only high-performance strikes (strongest buccal pressures) consistently activated the more ventral muscle regions—the posterior- and anterior-pointing cones (PPC and APC). For all locomotor behaviors studied, bass consistently activated the ventralmost region of the epaxial muscle (APC). Only the highest-performance swimming behaviors (C-starts and sprints) consistently activated the more dorsal muscle regions (PPC, DPA). Thus, in the highest performance swimming and feeding behaviors, bass recruit muscle fibers from all regions of the epaxial musculature, whereas for lower performance behaviors, fibers are recruited preferentially from the dorsal region for feeding and ventral region for locomotion. Finally, we found that even the strongest goldfish strikes produced submaximal muscle activity relative to C-start intensities. These relatively low intensities suggest that, in largemouth bass, the epaxial muscles underperform in terms of power output during suction feeding. Future studies will reveal whether species that require higher muscle power outputs, such as bluegill sunfish, show a different pattern. These results inform our understanding of how axial muscles that originally evolved for swimming have been co-opted to power suction feeding.

P1-41 JIMINEZ, M*; MURTAGH, N; WALDROP, LD; New Mexico Institute of Mining and Technology; *magdalena.jiminez@student.nmt.edu*

Micro Particle Image and Tracking Velocimetry for Assessing Flow in the Circulatory System of Tunicates

A key process in the development of closed circulatory vasculature is flow produced by the heart, which often begins as open circulatory flow. However, flow in open circulatory systems and microvasculature is often difficult to quantify. In the past, the movements of blood cells have been used as a proxy for fluid speed inside small vessels, but recent works have demonstrated that blood-cell speeds result in underestimating flow by up to 50%. In this study, we used micro particle image velocimetry (micro PIV) and particle tracking velocimetry (PTV) to quantify fluid flow speeds in the circulatory system of the tunicate, *Ciona savignyi*. Micro PIV is a technique that uses computational algorithms to reconstruct fluid flow velocity fields based on the bulk movement of illuminated tracer particles, and PTV tracks individual particles and reconstructs velocities from their displacements. We present a comparison between two artificial tracer particles (fluorescent microspheres and fluorescent liposomes) introduced by injection and two flow reconstruction techniques with the movements of blood cells at four points within the circulatory system, including the heart.

107-2 JINDRICH, DL; California State University, San Marcos; *djindrich@csusm.edu*

"Thinking for Writing" and "A Framework for Scientific Papers:" Using Writing to Support Reasoning, and Reasoning to Improve Writing

Strong, systematic reasoning is an important component of scientific progress (Platt, 1964). However, some areas of science instruction (e.g. Biology) often focus on rote learning, with relatively fewer opportunities for students to practice analytical and evaluative thinking (Zheng et al., 2008). Therefore, expanding opportunities for students to understand and apply scientific reasoning could benefit science education. Students have access to many resources (e.g. books, websites) to help with scientific reasoning skills. Moreover, written (and spoken) communication is necessary to express reasoned arguments and conclusions, and intrinsically involves reasoning skills (Rochford and Borchert, 2011). Many resources for scientific writing are also available to students. However, books and other resources often present scientific reasoning and writing separately. Academic curricula also may not allow for dedicated courses on reasoning and writing. Therefore, a resource that provides a concise review of reasoning and writing may be useful for supporting science education. I have developed two web-based modules based on the hypothesis that strong reasoning is a necessary part of clear scientific writing. The first module, "Thinking for Writing," presents foundational arguments for the importance of logical frameworks, simplicity, and specificity for developing critical understanding through written communication. The second module, "A Framework for Scientific Papers," applies the principles of the first module to the specific context of presenting hypothesis-driven research in the IMRaD format. The modules have the potential to support non-writing science courses such as laboratories by helping students improve scientific reasoning and communication.

S4-6 JOEL, A-C*; WEISSBACH, M; RWTH Aachen University, Germany; Johannes Gutenberg University Mainz, Germany, RWTH Aachen University, Germany; *joel@bio2.rwth-aachen.de*

Same Principles but Different Purposes: Passive Fluid Handling Throughout the Animal Kingdom

Everything on earth is subject to physical laws, thus they influence all facets of living creatures. Though these laws restrain animals in many ways, some animals have developed a way to use physical phenomena in their favor to conserve energy. Many animals which have to handle fluids, for example, have evolved passive mechanisms by adapting their wettability or using capillary forces for rapid fluid spreading. In distinct animals a similar selection pressure always favors a convergent development. But when assessing the biological tasks of passive fluid handling mechanisms, their diversity is rather surprising. Besides the well described handling water to facilitate drinking in arid regions, observed in e.g. several lizards, other animals like a special flat bug have developed a similar mechanism for a completely different task and fluid: Instead of water, these bugs passively transport an oily defense secretion to a region close to their head where it finally evaporates. And again some spiders use capillary forces to capture prey, by sucking in the viscous waxy cuticle of their prey with their nanofibrous threads. We want to describe the similarities and differences in the deployed mechanisms across the animal kingdom. Though focusing on fluid handling of well-studied reptiles, we aim to stretch over to other not as extensively studied species for which similar mechanisms for a different task are described.

3-1 JOHANSEN, IB*; HENRIKSEN, EH; SHAW, JC; MAYER, I; AMUNDSEN, P-A; ØVERLI, Ø; Norwegian University of Life Sciences, UiT The Arctic University of Norway; *ida.johansen@nmbu.no*

Towards the parasites' perspective on host pigmentation

Animal colouration has spurred some of the most active and controversial fields in evolutionary biology. Carotenoids are vital but limited resources in functions ranging from immunity to ornamentation. Parasite infection often correlates to intensity of carotenoid-based ornamentation and is believed to reflect an influence of parasites on host health. However, parasites can also shape host phenotype to their own advantage. Applying an extended phenotype approach to carotenoid distribution, we suggest the possibility that parasites affect this distribution depending on the host`s role in the parasites life cycle. Skin coloration (redness) and the ratio between skin and muscle coloration (red-red ratio) of sexually mature male Arctic charr (*Salvelinus alpinus*), is negatively correlated to infection intensities of the tapeworm *Eubothrium salvelini* that uses charr as a definitive host. Conversely, parasites that await trophic transmission are positively related to redness and red:red ratio. The positive association between *Diplostomum sp.* and redness/red:red ratio indicates parasite mediation not only related to immune function since they occupy the immune privileged eye. Thus, parasite mediation likely originates from more complex processes such as investment in reproduction. From the perspective of the parasite, promoting such investment could serve as an adaptation for trophic transmission. Conversely, opposing such investment could protect the final host from predation.

12-5 JOHN, JS*; BOERNER, K; DENUM, L; GASPARD, JC; WILLIAMS, TM; University of California, Santa Cruz, Mote Marine Laboratory & Aquarium, Pittsburgh Zoo & PPG Aquarium; *jsjohn@ucsc.edu*

Two stage recovery response in a shallow diving marine mammal; implications for boat avoidance cost in West Indian manatees

As a shallow diving marine mammal with a low energy herbivorous diet, West Indian manatees (*Trichechus manatus*) have developed adaptations to maximize energy efficiency. In addition to a low resting metabolic rate (RMR), our current research suggests that West Indian manatees have adapted their diving physiology to minimize oxygen debt during a dive. These adaptations, however, might not be optimized for the behavioral changes resulting from boat traffic, such as an increase in respiration variability. Despite a calculated aerobic dive limit greater than 18 minutes and a maximum observed dive duration of 24 minutes, the average dive duration for most behaviors is less than 3 minutes. To determine the energetic consequences of extended dives, we used flow-through respirometry to measure the energetic cost of stationary dives in 2 adult manatees at Mote Marine Laboratory & Aquarium (Sarasota, FL). For dives within preferred dive durations (< 3 min) the average recovery MR was 0.99 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$, 11% lower than the average resting MR (1.11 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$), indicating no incurred oxygen debt. For longer dive durations (4-8 min), the animals began to incur an oxygen debt, exhibiting an average recovery MR of 1.76 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ (59% higher than RMR) for a dive MR of 0.64 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. This suggests a dive physiology optimized for short duration dives and has implications for how these animals respond to anthropogenic disturbances in the wild.

26-3 JOHNSEN, S*; NIJHOUT , HF; Duke Univ.; *Sjohnsen@duke.edu*

Super-black butterfly uses stealth technology: honeycomb absorbing structures in the scales of the wings of Trogonoptera brookiana

While most research in biophotonics has focused on structural colors, and - to a lesser extent - structural whites, special structures are also required to make exceptionally black surfaces. Deep blacks are important for camouflage against bioluminescent searchlights in the deep-sea, and also for enhancing the contrast of color signals, as has been documented in the Superb Bird-of-Paradise (*Lophorina superba*) wings of the papilionid butterfly *Trogonoptera brookiana* are characterized by iridescent green triangles on an unusually black surround. We used specialized spectroscopic techniques to measure the reflectance of the black surface and found that, even at perpendicular incidence, which maximizes the specular contribution to the reflected light, the reflectance was only 0.05%, as low as the blackest known natural and artificial surfaces. Investigation by scanning electron microscopy (SEM) showed that the scales of the wings had an unusual honeycomb structure with a periodicity on the order of a wavelength of visible light. The structure contained melanin, but the importance of the structure itself was made clear by the fact that the gold-coated SEM samples remained black. The honeycomb structure strongly resembled the honeycomb radar-absorbing materials used in stealth aircraft technology. Indeed, if one scales the periodicity of the radar materials by the difference in wavelength between radar and visible light, one arrives at the periodicity of the honeycomb in the scales of *T. brookiana*. Similar structures have been found in other less-black papilionid butterflies (*Papilio paris,Troides helena, Pachliopta aristolochiae*) and have been investigated with an aim to increasing the efficiency of solar cells. We discuss the biological significance of this potentially convergent trait and its implications for signaling.

21-1 JOHNSON, D*; STAHLSCHMIDT, ZR; Univ. of the Pacific; *d_johnson23@u.pacific.edu*

What influences thermal maxima in urban ants?

Cities are rapidly expanding, and global warming is intensified in urban environments due to the urban heat island effect. Thus, urban animals may be particularly susceptible to climate change given their small thermal safety margins. We used two experiments to test three hypotheses related to understanding determinants of critical thermal maxima (T_{max}) in urban ants—specifically, that (1) body size, (2) preferred micro-environments, and (3) hydration status influence T_{max}. First, we manipulated water access (water provided *ad lib.* or restricted for 8 h) and determined T_{max} (knockdown temperature; range: 26-61°C) for 11 species common to cities in California's Central Valley that exhibit nearly 300-fold variation in body mass. Larger species had higher T_{max} after controlling for phylogeny, and water limitation in some, but not all, species reduced T_{max}. However, T_{max} was not influenced by the estimated active temperature (T_{active}) of ants or ant water content. Second, we used another water limitation treatment level (water restriction for 32 h) and more estimates of T_{active} in two focal, similar-sized species with different hydric and thermal sensitivities. Specifically, they varied greatly in T_{active} and T_{max} (*Prenolepis imparis*: 22°C and 40°C; *Formica moki*: 30°C and 51°C; respectively) and their T_{max} responded differently to water limitation (8 h water limitation reduced T_{max} in *P. imparis*, but not *F. moki*). Water limitation for 8 and 32 h similarly reduced T_{max} in *P. imparis*, but only 32 h of limitation reduced T_{max} in *F. moki*. Neither T_{active} nor body size affected T_{max} in either species. In sum, we found varied support for our hypotheses: inter- (but not intra-) specific variation in body size influenced T_{max}, T_{active} did not influence T_{max}, and the sensitivity of T_{max} to water availability varied across species. Our results highlight the importance of water as a valuable resource for animals in the Anthropocene.

54-2 JOHNSON, DE*; JONESBOGGS, JD; SMITH, JPS; Winthrop University, Rock Hill; *johnsond53@winthrop.edu*

Effects of Beach Nourishment on the Meiofauna: Not all Bad?

Beach nourishment, or the emplacement of dredged sand to mitigate the effects of erosion, has become a standard method of repairing tourist beaches. One long-term effect of nourishment is a coarsening of the beach, as the finer sediments wash away quickly, leaving behind shell-hash. This is of concern, as sediment grain-size is arguably the major abiotic determinant of meiofaunal community structure. Using sieving granulometry to determine sediment parameters and DNA metabarcoding to characterize the meiofaunal community, we have examined two beaches in North Carolina, USA that differ in nourishment history. Our preliminary findings show that there is a significant difference between the two in sediment parameters, with the nourished beach having a significantly greater mean grain-size (437μm vs 218μm; p= .0013) and a greater (160μm vs 41μm), but non-significant, sorting coefficient. Analysis of alpha diversity from the metabarcoding data shows that the nourished beach exhibits significantly higher diversity in all three measures used (Faith's PD, Chao1, and number of OTU's). It seems possible that the increased proportion of micro-habitats in the nourished beach supports higher community diversity. *This project was supported by INBRE Bioinformatics Pilot Project and INBRE RET grants to JSIII; student stipend support was provided from grant P20GM103499 (SC INBRE) from the National Institute of General Medical Sciences, National Institutes of Health.*

P1-222 JOHNSON, C*; GEORGE, SB; Georgia Southern University, Statesboro, GA; *georges@georgiasouthern.edu*

Factors Affecting the Facilitative Interaction Between Cordgrass Spartina alterniflora and Ribbed Mussels Geukensia demissa in Georgia's Salt Marshes

The ribbed mussel *Geukensia demissa*, can filter the total volume of water in a salt marsh twice a day. Making the salt marsh the most invaluable natural water purification system in the world. Ribbed mussels are found on raised portions of the marsh sediment called mounds. Mounds store water, reduce soil salinity stress, have a high organic content and promote cordgrass (*Spartina alterniflora*) growth. However, salt marshes are threatened by a variety of natural and anthropogenic factors. Rising temperatures may be altering the positive effect ribbed mussels and cordgrass have on each other. The purpose of this study was to examine the relationship between these two species in a saltmarsh at Tybee Island, Georgia. At this site, cordgrass height and density vary with distance from a winding tributary off of Tybee Creek. In addition, a road cuts through the high marsh. Four mounds located in the high marsh close to the tributary and four located in the mid marsh further away from the tributary were surveyed from spring through fall 2018. *Spartina* height and density and ribbed mussel abundance were determined on each mound. Temperature was monitored by placing one temperature logger in the high marsh and another in the mid marsh. Data from loggers indicate that the number of days when temperatures were above 110°F was higher in the high marsh than the mid marsh. Despite higher temperatures and proximity to the road, cordgrass density and height, and ribbed mussel abundance in the high marsh increased significantly over time. Mean mussel abundance in the high marsh was 39 ± 2 and in the mid marsh was 27± 2. The proximity to the tidal creek may have a positive effect on cordgrass growth which in turn lowered the temperatures and provided suitable shelter for ribbed mussels.

74-2 JOHNSON, B*; SEARLE, J; SPARKS, J; Cornell University; *bbj23@cornell.edu*

Morphological Drivers of Physiological Performance in Lungless Salamanders

The relationship between body size and whole-organism metabolic rate is one of the best documented physiological patterns across the tree of life. However, cell size also influences metabolic rates, leading to potential interactions between body size and cell size in driving physiological function. Cell size is itself determined by genome size, thus the physical size of the genome has a potential functional, "nucleotypic" effect on organismal physiology, particularly in lineages with adequate variation in genome size. I investigate this effect in eight species of lungless salamanders (Urodela: Plethodontidae). Lungless salamanders display substantial variation in genome size relative to other vertebrates. Critically, they respire and transport water entirely through the integument. Genome and cell size variation in this group thus have direct functional consequences by modulating the structure and function of skin, the primary site of respiratory gas and water exchange. By sampling across genome size and body size variation in this group, I quantify variation in gas and water transport as a function of genome-, cell-, integument-, and whole-organism level morphological interactions to determine how morphological variation drives plethodontid physiological function.

5-4 JOHNSON, KM*; CASAS, SM; LA PEYRE, JF; KELLY, MW; Louisiana State University; *kmjohnson@lsu.edu*

The Influences of Environment and Dermo Infection on DNA Methylation in the Eastern Oyster Crassostrea virginica

Populations of eastern oysters (*Crassostrea virginica*) in the Northern Gulf of Mexico will be challenged by predicted changes in ocean temperature and salinity. As environments change a combination of phenotypic plasticity and local adaptations will be important mechanisms that may allow one population to persist and not another. Recent advancements in the use of reduced representation bisulfite sequencing and the release of a reference genome for *C. virginica* provides new opportunities to explore the extent to which DNA methylation is shaped by the environment. Recent evidence suggests that there are population specific patterns in DNA methylation in *C. virginica* and that DNA methylation is significantly correlated with variability in gene expression. In this study we have explored changes in DNA methylation between 2 populations of *C. virginica* collected from a high and a low salinity site along coastal Louisiana. Crosses within each population were conducted at Grand Isle Hatchery (LA) and the progeny were out-planted at either a medium-high salinity site (Grand Isle, LA; 19.2 psu) or at a low-salinity site (Chauvin, LA; 9.7 psu). To test for the effects of rearing environment and dermo infection intensity on DNA methylation we sampled 20 oysters for each population from each site after 1 year. We assessed changes in DNA methylation using reduced representation bisulfite sequencing (RRBS) and focused our comparisons on changes in methylation within a population but between out-plant sites and for dermo infection between populations within a site. This approach provides the opportunity to explore the extent to which genotype, infection intensity, and environment influence DNA methylation patterns in *C. virginica*.

P2-187 JOHNSON, N.J.*; BROWN, J.M.; DEAROLF, J.L.; AVERY, J.P.; Hendrix College, Conway, AR, Univ. of Alaska Fairbanks; *johnsonnj@hendrix.edu*

Effect of multi-course prenatal steroids on fiber-type profile and enzyme activity in the guinea pig rectus thoracis

When a mother is set to give birth prematurely, she is often given glucocorticoids to accelerate the development of her fetus' lungs. Despite the steroids' known effect on lung development, little is known about the effects on ventilatory muscles. We hypothesize that exposure to prenatal steroids accelerates the development of these muscles. Thus, the breathing muscles of fetuses exposed to these steroids will have fiber-type profiles and enzyme activities more similar to those of 1-day-old neonatal muscles than the muscles of control fetuses. Pregnant guinea pigs were injected with either betamethasone (0.5 mg/kg body weight - treated) or sterile water (control) at 65%, 75%, and 85% gestation, and samples of the fetal rectus thoracis (RT) muscle were collected. Sections of the treated and control RTs were cut with a cryostat and stained for their reaction to myosin heavy chain antibodies. The antibody A4951 was used to stain for type I, slow-twitch fibers, and the antibody 2F7 was used to stain for type IIA, fast-twitch oxidative glycolytic fibers. Using ImageJ software, the diameter and density of staining for 2F7 was measured for the fast-twitch fibers. To determine the glycolytic and oxidative capacities of fetal, neonatal (1-day-old), and adult RT, lactate dehydrogenase (LDH) and citrate synthase (CS) activities were measured. The LDH and CS data will hopefully allow us to draw a conclusion about enzyme activity throughout development. If the treated fetal and neonatal data are similar, it would support the hypothesis that prenatal steroids accelerate fetal breathing muscle development. Thus, premature infants exposed to prenatal steroids will be able to ventilate their lungs just as well as full term infants.

88-3 JOHNSON, AS*; ELLERS, O; ETZEL, R; KHORIATY, J; Bowdoin College; *ajohnson@bowdoin.edu*

The oscillatory gait of high-speed sea stars: Do sea stars of varying morphology vary stride length or step frequency to change speed?

We have confirmed that at least five species of sea stars have a special oscillatory gait that they use to increase their speed. Although this gait is driven by coordinated movement of tens of tube feet, or podia, rather than a few well-defined legs, these gaits have an identifiable step frequency and stride length. The product of step frequency and stride length is speed, and changes in either of these variables could be responsible for speed increases. In human studies, subjects can be asked to aim for walks with constant stride frequency, constant stride length, constant speed or preferred stride length and frequency across a range of speeds. In sea stars we cannot survey such a range of conditions, but we can get a range of behaviors by studying voluntary gaits within individuals, within a species and across species (other possibilities might include different temperatures and motivational states). We filmed many individuals of three species of sea star (*Protoreaster nodosus*, *Asterias forbesi*, *Luidia clathrata*), for whom periodic vertical locomotory oscillations are correlated with increases in speed. We found that most of the variation in speed was due to changes in stride length. Stride frequency varied less and sometimes even declined with increasing speed. These correlates of speed suggest that this locomotory system behaves like a forced damped harmonic oscillator. The frequency may be related to sea star mass and the stride length may be related to the length of the podia, which are hydraulically variable in length. By observing among a size series within a species and by surveying among species, a range of mechanical conditions varying in mass and density and allometric morphology can be surveyed to uncover underlying mechanisms and constraints.

123-6 JOHNSTONE, J/B*; RAHMAN, MD/S; University of Texas Rio Grande Valley; *jackson.johnstone01@utrgv.edu*

Impacts of rising temperatures on gonadal functions, heat shock protein expression, and cellular apoptosis in Atlantic sea urchin

Increasing surface sea temperatures are having an increasing impact on marine environments. Sea urchins are ideal model organisms to focus on, as they are excellent indicator species in regards to their response to global climate changes. They are also an ancient and relatively simple species, meaning that there are fewer internal mechanisms to deal with when observing responses. In this study, we tested the effect of higher temperatures on reproductive functions, heat shock protein expression, and ceolomic fluid (CF, a body fluid which regulates important physiological processes) conditions in Atlantic sea urchin at three different temperatures. Ten sea urchins were placed in each of six aquariums (capacity: 20-gallon) with high temperatures (28 and 32oC) and control variable (24oC) under controlled laboratory conditions for a 7-day period. For this experiment, the reproductive functions and heat shock protein expression focused on both male and female specimens. Sea urchin exposed to high temperature had the lower gonadal growth (gonad weight/body weight*100) compared to controls. The percentage of mature eggs (ova) was also significantly lower at high temperature compared to controls, indicating impaired ovarian functions at high temperatures. Sperm production also displayed a tendency to decrease from the lower to higher temperatures. Sea urchin exposed to high temperature showed an increased heat shock protein expression in eggs, follicles, and sperm, as well as increased cellular apoptosis and decreased CF pH compared to controls. These results suggest that elevated water temperature decline/acidify CF pH which might be involved in the impairment of reproductive functions and cellular apoptosis in Atlantic sea urchin.

P2-41 JONES, AE*; WEBB, JF; Univ. of Rhode Island; *aubree_jones@my.uri.edu*

The Lateral Line System of Larval Brook Trout, Salvelinus fontinalis: Early Indications of Life in Flowing Water

The ecomorphology of the mechanosensory lateral line (LL) system of teleost fishes with reference to the flow regimes that they inhabit is not well understood. The canal neuromasts (CN) and superficial neuromasts (SN) of the LL system occur in varying proportions among species. Several authors have documented relatively high numbers of CNs and low numbers of SNs in adult salmonids (Order Salmoniformes), which is unusual among teleosts. Brook trout (*Salvelinus fontinalis*), a commercially important species, is routinely raised in hatcheries and are available for study. Here we describe the morphology and distribution of the cranial CNs and SNs in alevin and fry to determine when the relative numbers of CNs and SNs observed in adults are established. An ontogenetic series (0-52 days post-hatch, dph; n=13 spec.; from wild-caught parents) were prepared for SEM. Length, width, and area of presumptive CNs (PCNs) and SNs were determined. By 14 dph (yolk sac still present), PCN and SN morphologies have diverged, with larger, oval PCNs and smaller, round SNs. By 45 dph (after feeding has begun), preopercular PCNs have begun to sink into a canal groove. Multiple PCNs are also found in each of the other canal series: supraorbital (n=12), infraorbital (n=10), preopercular (n=6), and mandibular (n=8). However, only 5 lines of SNs are present on the head; SN number is relatively low, especially when compared to that in stomiiforms (another group of basal euteleosts), and otophysans (e.g., zebrafish, tetras, goldfish), which have 100's of SNs and tend to live under low flow conditions. The high number of cranial CNs may be related to their life in flowing water and the functional significance of this will be discussed.

37-2 JONES, M*; NAGALINGUM, N; California Academy of Sciences; *mjones@calacademy.org*

Phylogenetics of grammitids (Grammitidoideae): Using molecular data and morphological characters to identify Peninsular Malaysian ferns

The subfamily Grammitidoideae (grammitid ferns in the family Polypodiaceae) encompasses 33 genera and approximately 750 species of ferns distributed across the neotropics, southeastern Asia, and Oceania. Included genera display significant morphological variation in characters such as rhizomes and rhizome scales, laminae, and arrangement of sori and sporangia. Many grammitid species ferns are undescribed, making it difficult to protect the biodiversity of ecosystems to which they belong. In particular, the Malaysian Peninsula is a focus for conservation efforts -- the biodiversity of this region is rich and includes endemic species, and grammitids thrive in mossy montane forests of this region. We sampled ferns from Penang Hill to analyze morphological characters using herbarium specimens, photographs from online herbaria, and dichotomous keys to identify the samples. We sequenced five chloroplast loci and incorporated the sequences into a dataset consisting of 258 identified species of grammitid ferns to generate maximum likelihood tree and Bayesian trees that establish relationships between identified species and our samples. Both samples are closely related to other species from southeastern Asia, placing them in the tropical Asian clade. One of the samples likely belongs to the genus *Ctenopterella* (*Ctenopteris*). The distribution of this genus throughout our trees strongly suggests that it is not monophyletic. The other sample is related to the genera *Radiogrammitis* and *Oreogrammitis*, based on molecular analysis, but examination of morphological traits indicates that it not only belongs to *Radiogrammitis*, it is a species new to science, or at least to Malaysia.

85-2 JONES, JA*; BOERSMA , J; ENBODY, ED; FUXJAGER, MJ; ROSVALL, KA; SCHWABL, H; WEBSTER, MS; KARUBIAN, J; Tulane University, Washington State University, Wake Forest College, Indiana University, Cornell University; *johnajones91@gmail.com*

Experimental inhibition of peripheral androgen receptors dampens ornament expression in a female tropical passerine

In vertebrates, the androgen testosterone (T) regulates a variety of signals used to communicate, but our understanding of the relative importance of circulating T versus receptor sensitivity in predicting signal expression remains limited. This limitation is particularly relevant for females, however, considering that high T levels can be costly. Previous studies have shown that T-implanted females in dichromatic species may develop a partial, male-like plumage, stressing that while circulating T is important, in isolation, circulating T alone is not sufficient to explain patterns of phenotypic differentiation between sexes. Here, we explore the proximate mechanisms of female ornamentation in white-shouldered fairywren (Malurus alboscapulatus), a tropical passerine that varies in female, but not male, ornamentation among populations. In a population where both males and females exhibit black eumelanin feathers and white scapular patches (defined here as ‘ornamented'), we implanted both sexes with the potent antiandrogen bicalutamide, a drug that blocks androgen receptors. We found that the white scapular patch of females implanted with bicalutamide regrew feathers tipped in melanin pigments, but not in males. However, most of the ornament regrew normally, suggesting a role of T in regulating partial ornament expression. These results suggest that patterns of phenotypic divergence in ornamentation between sexes and among populations is a complex interaction between circulating T, androgen receptor sensitivity, and the resulting gene expression which warrants further exploration.

P2-275 JONES, J/L*; COUNTERMAN, B; HOFFMANN, F; Mississippi State University; *jj1827@msstate.edu*

Adaptive Evolution of Argonaute Genes in Lepidoptera Genomes

The Argonaute genes of the Ago and Piwi subfamilies mediate a broad range of processes from development to antiviral immunity. These genes are conserved across the animal phylogeny and are crucial for the silencing of transposable elements. The adaptive evolution of these genes has also been implicated in driving hybrid dysgenesis in closely related species. Differences in the Argonaute genes between species are thought to lead to differences in transposable elements family abundance that results in genomic incompatibilities. Studies in *Drosophila* suggest such incompatibilities may be important in the evolution of postzygotic isolating barriers between closely related species. Here, we leveraged an abundance of available Lepidoptera genomes to test for adaptive evolution of the Argonaute gene family in three families of butterflies. We further investigate the role of Argonaute gene family in early stages of species divergence by testing for adaptive evolution between closely related, hybridizing species of *Heliconius* butterflies. Preliminary analysis shows evidence of adaptive evolution for a single gene, *Ago1*, across the Lepidoptera phylogeny. Population genetics analysis also suggest evidence of rapid divergence between hybridizing *Heliconius* for another ago gene, *Ago3*. Collectively, our findings suggest most genes in the Argonaute family are under strong purifying selection, however *Ago1* and *Ago3* showed diversity which may indicate their role in adaptive evolution.

37-6 JORGE, JF*; HARRISON, JS; MANOS, PS; PATEK, SN; Duke University; *jfj7@duke.edu*

Biomechanics of ballistic seed dispersal in the witch hazel (Hamamelis)

Ballistochoric plants project seeds away from the parent plant so that offspring can avoid competition for nutrients and sunlight. Their diversity of seed shapes and sizes reflect the many mechanisms used for ballistic seed ejection. If the driving factor for these mechanisms is the dispersal distance, then plants with larger seeds would require more robust mechanisms to effectively disseminate their seeds. Species in the witch hazel genus *Hamamelis* launch seeds that are large (average of 0.04 g, sample size 33 seeds) when compared to seeds from most ballistochoric plants (seeds of similar, previously studied systems range from 10^{-4} g to 10^{-2} g). The explosive dispersal of witch hazel seeds has yet to be fully resolved, due to their extremely fast and brief movement. Now, through high speed videography, we elucidated these transient events. We collected seed capsules from four *Hamamelis* plants on Duke's campus and extracted from their seed capsules the endocarps containing the seeds. We firmly secured each endocarp to the base of a desiccation chamber and recorded with a high speed camera (100,000 fps). The seeds were ejected with an average maximum velocity of 8.8 m/s and an average maximum acceleration of 120,000 m/s^2 (sample size of 33 seeds, from 4 plants). Through our velocity calculations and an estimate of drag, we expect that the seeds can travel 5 m from their host plant. Endocarps with greater mass launched seeds with greater kinetic energy and maximum velocity. *Hamamelis*, which disperses seeds that are almost half the mass of the mechanism used to expel them (seed mass to endocarp mass ratio of 0.43), can provide insight into how the mass of the seed influences its dispersal mechanism.

27-5 JOSEFSON, CC*; HEARD, RE; HOOD, WR; Auburn University, Auburn, AL; *ccj0011@auburn.edu*

Trans-generational effects during development following maternal immune challenge in a lactating rodent

The environment that an individual experiences early in life can have long-lasting impacts on its physiological phenotype. These adjustments are hypothesized to be adaptive. That is, if the developmental environment is predictive of later life conditions, the physiological changes associated with this adaptation are predicted to improve subsequent reproductive performance and survival for that individual. Thus, although there is an ontological program during the fetal and neonatal periods, there is also the capacity for the individual to adjust their phenotype in order to maximize future reproductive success. Small rodents, such as mice (Mus musculus), are particularly useful models for understanding how maternal investment shapes offspring because allocation to reproduction is high and likely pushes females to their physiological limits. Here, we used outbred laboratory mice to investigate the impact of maternal immune challenge with KLH (keyhole limpet hemocyanin, a non-replicating antigen) on physiological characteristics of offspring. Mothers were placed in three experimental groups based on their reproductive intensity and whether or not they received an immune challenge including 1) control and lactating (PBS+L), 2) immune-challenged and lactating (KLH+L) and 3) immune-challenged and concurrently gestating and lactating (KLH+PL). Body and organ masses of the pups were recorded, and gene expression for glucocorticoid and mineralocorticoid receptors, growth hormone and insulin-like growth factor 1 receptors, and pro-inflammatory cytokines were quantified. Our results support that maternal immune challenge and maternal reproductive intensity impact offspring physiology. Together, this study provides empirical evidence in mammals that is critical to furthering our understanding of factors that contribute to offspring life-history variation.

64-3 JUAREZ, Y S*; DI SANTO, V; WILHELMUS, M M; Univeristy of California, Riverside, Harvard University; *ysanc012@ucr.edu*

Robokrill: a metachronal robotic swimmer

Drag-based propulsion via metachronal beating of neighboring appendages is commonly found among species of crustaceans that undergo long-distance migrations in the ocean. While previous experimental studies have analyzed the kinematics of this swimming gait within the context of propulsive e ciency, the e ect of stroke kinematics and morphology on transport of the surrounding fluid is not well understood. In this talk, we present a newly developed metachronal robotic swimmer designed to mimic the metachronal swimming of Antarctic krill, Euphausia superba, during forward propulsion to analyze aspects of metachrony that are challenging to isolate in natural systems. In particular, we aim to understand which design parameters can be leveraged to maximize transport. We present particle image velocimetry measurements during vertical migration of a single swimmer and compare its hydrodynamic signature to flow fields of real organisms presented in the literature. We discuss the feasibility of leveraging this system to engineer new self-propelled robots that maximize transport in a transitional Reynolds regime.

122-5 JUDSON, JM*; HOEKSTRA, L; HOLDEN, K; POLICH, R; ADAMS, C; BRONIKOWSKI, A; JANZEN, F; Iowa State University; *jjudson@iastate.edu*
The role of color, immunity, and sexually dimorphic traits in female mate choice
From the colorful dewlap of *Anolis* lizards to courtship displays in turtles, reptiles exhibit a wide array of traits presumed important in sexual selection. Many reptiles exhibit sexually dimorphic pigmentation or energetically costly displays that have few explanations beyond their potential role in female choice. However, limited evidence exists for female reptiles actively choosing mates before copulation. If female choice and sexually dimorphic traits are positively related, then intersexual selection should be an important evolutionary process maintaining sexual dimorphism. This possibility is particularly interesting in reptiles with temperature-dependent sex determination (TSD), where the genomes are identical between the sexes. We used the painted turtle (*Chrysemys picta*) as a model reptile to understand which male traits may influence a female's choice of mates. We held turtles in outdoor ponds April-August of this two-year study, where they were allowed to mate and nest. We measured body size, male claw length, arm stripe color, and immune health in adults. We collected and incubated eggs in 2016 and assigned parentage for all hatchlings using a panel of 96 maximally-informative SNPs. We considered relationships between siring success and the measured sire traits as evidence for female choice, providing novel insight into the role of color, immunity, and sexually dimorphic traits in female mate choice in a reptile with TSD.

61-7 JUHN, MS*; VAN VALKENBURGH, B; ALFARO, ME; Univ of California, Los Angeles; *markjuhn@ucla.edu*
Exploring Macroevolutionary Ratchets as a Potential Driver of Clades in Decline
Diversity declines are well documented and widespread in the fossil record, but the mechanisms that drive the observed dynamics remain unclear. Macroevolutionary ratchets have been proposed as a potential driver of decline, where selection favors the loss of early generalized forms, which results in more vulnerable specialized forms late in the history of the clade. While empirical evidence for the presence of a macroevolutionary ratchet has been demonstrated in the North America canid record, the general clade dynamics accompanying this pattern have not yet been explored. We used simulations to explore the relationship between trait evolution, extinction, and clade decline under macroevolutionary ratchet-type scenarios. To simulate the macroevolutionary ratchet, we modeled the extinction rate of each lineage as a function of its trait value. We used a Brownian motion model with trend to reflect the ratchet-like effect of specialization, where clade is forced to become more specialized over time. Our simulations confirm that a macroevolutionary ratchet-type scenario will lead to a diversity decline trajectory. However, the diversity trajectory after peak diversity is not always unidirectional, suggesting that clades may be able to recover from short periods of decline. Additionally, clades where the relationship between trait value and extinction was high were unable to generate enough diversity in the rise phase in order to experience decline. Inferences from these simulations can be used to detect the signature of the macroevolutionary ratchet in empirical clades. Our results clarify how trait evolution can drive decline under a range of parameter values and provides additional insights on a mechanistic hypothesis of clade decline.

P3-144 JULICK, C*; TENGER-TROLANDER, A; GREEN, A; KRONFORST, M; MONTOOTH, K; Univ. of Nebraska-Lincoln, Univ. of Chicago, Univ. of Michigan; *cjulick@unl.edu*
Divergence in metabolic plasticity in response to seasonal rearing conditions among migratory and non-migratory populations of monarch butterflies (Danaus plexippus)
My current research explores the divergence in metabolic plasticity in response to seasonal rearing conditions among migratory and non-migratory populations of monarch butterflies. The long migration that returns individuals to overwintering sites in Mexico is four generations removed from the individuals that migrated north during the spring and summer. This natural history predicts developmental plasticity for many aspects of flight physiology and energy allocation to enable long-distance migration in the context of a life-history strategy that requires conservation of energy to invest in reproduction after overwintering. Furthermore, not all populations migrate, allowing for population divergence in migration-associated traits. Using migratory (North American) and non-migratory (Costa Rican) populations of monarchs reared for two seasons under both non-migratory (summer) and migratory (fall) conditions, we tested the prediction that migratory populations have greater plasticity in metabolic performance in response to rearing conditions than do non-migratory populations. We find that Costa Rican populations have elevated resting metabolic rates in response to fall migratory rearing conditions. Under these same conditions, the Costa Rican population also has higher resting metabolic rates relative to the North American population. Together, these patterns indicate that North American, but not Costa Rican, populations can maintain metabolic homeostasis across seasonal rearing environments. We also find that the two populations have different metabolic scaling coefficients for their flight metabolic rate in response to fall migratory rearing conditions.

41-2 JURESTOVSKY, DJ*; ASTLEY, HC; Univ. of Akron, Ohio; *djj64@zips.uakron.edu*
The Effect of the Zygosphene/Zygantrum Joint on the Range of Motion in Snake Vertebrae
Joint articulations determine range of motion (ROM), allowing or restricting particular motions to balance stability and flexibility. Snakes have a unique zygosphene/zygantrum joint in their vertebrae (either minimal or absent in all other vertebrates), but the function of this joint is poorly understood. To experimentally determine the role of the zygosphene/zygantrum articulation in the range of motion in snake vertebrae, two sequential mid-body vertebrae of a cornsnake (*Pantherophis guttatus*), boa (*Boa constrictor*), and rattlesnake (*Crotalus viridus*) were CT-scanned, segmented out, and 3D printed (14x size). Two copies of the posterior vertebrae were printed, one unaltered and one with the zygosphene digitally removed. Motion capture cameras were used to record the angular ROM in yaw (lateral bending), pitch (dorsoventral bending), and roll (axial torsion) as the joint was manually manipulated. Removal of the zygosphene increased yaw ROM but did not affect pitch. In the unaltered vertebrae, roll ROM was minimal for all combinations of pitch and yaw. In the altered vertebra in the cornsnake and boid, roll ROM was unconstrained only when the pre- and post-zygapophyses were no longer articulated (at high yaw angles), a condition that was not possible when the zygosphene was present. In the rattlesnake, roll ROM was minimal for both altered and unaltered vertebrae, as the pre- and post-zygapophyses were unable to disarticulate. Thus, it appears the zygosphene/zygantrum joint acts as a bony limit preventing the vertebrae from reaching high yaw angles where roll could occur, strengthening the joint without sacrificing flexibility.

103-7 JUSUFI, A*; VOGT, D; WOOD, RJ; Max Planck Institute, Germany, Harvard University; *ardian@is.mpg.de*

Co-Contraction facilitates Body Stiffness Modulation during Swimming with Sensory Feedback in a Soft Biorobotic Physical Model

Undulatory motion of the torso is a salient feature of locomotion in many vertebrate taxa, particularly in fishes and reptiles. Although important insights into the mechanics of swimming were uncovered in numerous studies of body kinematics and muscle activity patterns, it has been challenging to investigate how the extent of lateral muscle activation affects propulsive performance due to the difficulties associated with modulation of in vivo muscle activation in freely-swimming fishes. To gain insight into co-contraction and body stiffness control we previously built a compliant physical model with soft bending actuators that allows for actively-controlled shape changes on the body. A parameter sweep of cyclic undulation frequencies and co-contraction phasing was performed and self-propelled speed measured. Measurement of thrust as a function of co-contraction phasing between the right and left sides in the undulatory swimming of our model revealed that antagonistic co-activation for a small fraction of the cycle period can increase thrust. Expanding upon this, we sought to determine the extent to which bilateral left-right co-activation has the capacity to alter the stiffness of the body, we carried out experiments to measure the body stiffness directly. When soft actuators were co-activated we measured an increase in stiffness from 18 to 29 N/m for pressure values of 0, 15, 20, 30, and 40 kPa. Moreover, we integrated hyperelastic soft sensors for estimation of body curvature. The soft sensors were mounted laterally along the soft pneumatic actuator to close the loop. Sensors contained microchannels filled with liquid metal eutectic Gallium Indium. This marked the first time an eGaIn-based soft sensor was tested under water. Despite the hydrodynamic pressure, it allowed for measurement of strain changes of body curvature. During bending of the soft actuator the fin curvature increases. The associated length changes correlated with changes in electrical resistance in the liquid metal within microchannels. Resistance increased proportionally with bending in the range of actuator pressurization from 0.13 to 0.66 bar, thus enabling fin displacement amplitude control. Sensory feedback will allow for applying the necessary pressure correction to remain at the desired body-caudal curvature at a range of water flow speeds. This biorobotic platform provides a physical model for testing hypotheses on how swimming performance can be affected by modulation of torso stiffness.

33-5 KAASHOEK, M*; NAUWELAERTS , S; AERTS , P; University of Antwerp, Belgium, University of Antwerp and University of Ghent, Belgium; *marielle.kaashoek@uantwerpen.be*

Comparison of the instantaneous axis of rotation between different monodactyl equids

The Equidae belong to the Perissodactyla, which are also known as the odd-toed ungulates. During the Miocene, at least four different lineage within the Equidae reduced the number of functional digits on the forelimb to one, also referred to as monodactyly. The *Equus* lineage, including asses, donkeys, horses and zebras, is the only remaining lineage. This study is part of a larger project that will test hypothesis regarding monodactyly and the disappearance of the three extinct lineages. The aim of this cadaver study is to compare the instantaneous axis of rotation (IAR) of all forelimb joints between different monodactyl equids. The IAR can be used to describe the three-dimensional motion of two subsequent segments. Cadaver forelimbs of a przewalskii, a zebra, different horse breeds and several non-equids (including an alpaca, a lion and a tapir) were used to determine the IAR over the entire range of motion for all forelimb joints. Standardized cuts were made at the midlevel of each segment and bone pins attached with reflective marker triads were drilled into the forelimb bones. Each forelimb joint was manually moved independently through flexion-extension, abduction-adduction and internal-external rotation. The three-dimensional coordinates of the marker triads were recorded using an infra-red six camera system. With a customized MATLAB script, based on the software package KineMat, IAR properties were calculated over the entire range of motion. Within the monodactyl species, the different joints displayed different IAR behaviours, but for each joint the IAR properties were similar between the different monodactyl species. Comparable orientations and positions of the IAR suggest that different species can display similar movements between the different forelimb segments, and thus similar kinematics.

P1-32 KACZMAREK, EB*; KOLMANN, MA; GREAR, ME; SUMMERS, AP; Brown University, George Washington University, Pacific Northwest National Laboratory, University of Washington; *elskabette@gmail.com*

Thorn on my side? Form, function, and evolution of defensive weaponry in doradid catfishes

Doradid catfishes are weaponized with pectoral and dorsal fin spines with lateral rows of thorn-like barbs. These spines often reach 30% of body length and can be abducted and locked into place. The pectoral girdle, which supports the pectoral spines, has a broad ventral surface with an interdigitating median suture, in contrast to the slender ventral arms of the pectoral girdle in other teleosts. We used micro-CT scans, finite element analysis, mechanical testing, and phylogenetic comparative methods to study the morphology, function, and evolution of these defensive adaptations in doradids. The median suture is formed by a zipper-like series of projections, which differ in three-dimensional morphology from the well-documented interdigitating sutures of cranial bones. We predict this suture permits flexion under mediolateral compression. This is supported by the results of both static compression of a finite element model of a pectoral girdle and spines and by compression of the pectoral girdle using a mechanical testing system. We also tested for evolutionary integration between barb and girdle morphologies and found a strong phylogenetic signal in the morphometrics of the pectoral spines, girdle, and median suture. A phylogenetic partial least-squares regression indicated strong integration between barb and girdle morphologies overall; however, phylogenetic generalized least squares (PGLS) regressions on paired traits did not find strong relationships between suture interdigitation and either pectoral girdle or spine morphometrics. PGLS results did find strong integration between girdle width and barb cross-sectional area, suggesting that as spines get stiffer, the pectoral girdle gets broader.

P3-150 KAHN, AS*; LORD, JP; KATIJA, K; BARRY, JP; Monterey Bay Aquarium Research Institute, Moss Landing, CA, Moravian College, Bethlehem, PA, Monterey Bay Aquarium Research Institute. Moss Landing, CA; *akahn@mbari.org*

Respiration and Water Processing by Glass Sponges in Sur Ridge, a Dense, Deep-water Coral and Sponge Habitat

Benthic communities beneath the ocean's photic zone cannot rely on locally produced food as light cannot penetrate to fuel photosynthesis. Deep benthic communities thus rely mainly on imported nutrients, either as material sinking from the photic zone or arriving via lateral currents. The food that arrives is often limiting, yet in some locations, dense communities manage to persist and even flourish. Sur Ridge off the coast of Big Sur, California is such a community. This deep submarine ridge (800-1700 m) has diverse and dense communities supported in part by habitat-forming, deep-sea corals and sponges. The impact of corals and sponges as foundation species is clear, but what affects their distributions is not fully resolved. To investigate this, we focused on sponges to understand 1) their own energetic needs via metabolic rate, and 2) the effects of pumping activity on the surrounding water. We measured *in situ* respiration and activity levels, as pumping rates, using optical oxygen sensors and a novel deep particle imaging velocimetry system (DeepPIV) deployed by remotely operated vehicle. Respiration was variable between species, with some having very constant oxygen removal rates and other species with removal rates that varied even over a 5 minute span. DeepPIV revealed that the glass sponges of Sur Ridge pump many times their own body volume of water each day, with pumping rates dependent on osculum size. Given the efficient particle capture of other glass sponge species, this may indicate that dense patches of sponges at Sur Ridge can affect the overlying water column and create different microenvironments for other benthic fauna.

136-1 KAHRL, AF*; SNOOK, RR; FITZPATRICK, JL; Stockholm University, Stockholm; *ariel.kahrl@gmail.com*

Sperm Evolution Across the Animal Tree of Life

Despite their homologous function of fertilizing eggs, sperm exhibit incredible morphological diversity across the animal kingdom. There is ample evidence that post-mating sexual selection (sperm competition and cryptic female choice) drives sperm diversity at the family- or genus-level. However, the vast majority of variation in sperm morphology exists among taxonomic groups, and likely has deep evolutionary roots. Yet, we know surprisingly little about how sperm diversification is influenced by selective agents at the macroevolutionary scale of the animal tree of life, such as variation in the fertilization environment (internal vs. external fertilization) and reproductive mode (egg-laying vs. live-bearing). Here, we examine sperm morphology from >4000 species, spanning all major phyla of animals, to generate a macroevolutionary view of sperm evolution across 400 million years of animal evolution. We show that transitions in both fertilization and reproductive mode prompt evolutionary responses in sperm size. Specifically, externally fertilizing species have significantly smaller sperm than internal fertilizers. We argue that sperm dilution associated with external fertilization imposes limits on the evolution of sperm size, while sperm-sperm and sperm-female interactions within the female reproductive tract in internal fertilization drives evolutionary increases in sperm size. Within internal fertilizers, oviparous species have significantly larger sperm than both ovoviviparous and viviparous species. This suggests that because the cost of reproduction differs for ovi-, ovovivi-, and viviparous species, post-mating selection on sperm morphology may also vary. Our results highlight the potential for large-scale databases and analyses spanning the animal tree of life to shed light on the macroevolutionary drivers of evolutionary diversification in animals.

12-7 KAIYALA, KJ; LIGHTON, JRB*; Univ. of Washington, Sable Systems International; *lighton@sablesys.com*

Full Derivation and Verification of a Simplified Technique for Accurate Measurement of Energy Expenditure

Energy expenditure (EE) measurement can take place via direct or indirect calorimetry. With indirect calorimetry, O2 consumption and CO2 production rates are typically both required in order to calculate EE. This arises because the oxycaloric equivalent, required to transform O2 consumption rate to EE, varies with the respiratory quotient (RQ). In 1949 J.B. Weir derived an equation for calculating EE from O2 consumption and CO2 production rates, and had the key insight that CO2 dilution of the oxygen signal could counteract the inverse dependence of the oxycaloric equivalent on RQ. This insight was rediscovered sporadically in the coming years, but has not been widely used as its validity has not been rigorously demonstrated from first principles. Here, we present the first rigorous derivation of the formula for transforming O2 consumption rates, in the presence of CO2 dilution, into EE directly. We show that this formula applies only to ambient O2 levels close to normoxia, and also validate the formula using 168 individual mouse-days of EE data across a temperature range of 19 - 29C. Given the calibration uncertainties of CO2 calibration gases, this method provides a highly accurate calculation of EE, as it does not depend on CO2 analysis at all. However, if CO2 analyzers are used, it provides a method for validating their correct operation, given the 24h equivalence of food quotient and RQ (by Hess's law of Constant Heat Summation). We further demonstrate that drying of the sample air is not necessary if water vapor pressure and barometric pressure are measured, allowing the dilution effect of water vapor to be removed using Dalton's law of partial pressures.

65-6 KAJI, T; FARLEY, G; JORGE, J; LONGO, S; HARRISON, J; PATEK, S; PALMER, AR*; Univ. of Alberta, Duke Univ.; *rich.palmer@ualberta.ca*

Who Knew? Ultrafast Limb Movements in an Amphipod that Snaps

Ultrafast appendage movements have evolved in many arthropod groups including snapping shrimp, mantis shrimp, trap-jaw ants and smashing-mandible termites. We discovered such motions in another arthropod group: maerid amphipods. We confirmed prior anecdotal reports that male amphipods of the genus *Dulichiella* produce a snapping sound with their second gnathopod. This massively hypertrophied gnathopod, which occurs primarily on the right side, exhibits pronounced positive allometry and in large males of *Dulichiella appendiculata* may exceed 20% of the total body weight. Preliminary high-speed video recordings of gnathopod closing (more than 200,000 fps) and synchronized audio recordings revealed a) angular velocities among the highest known in animals, b) surprisingly large appendage recoil motions, c) occasional formation of cavitation bubbles, and d) hints of an unexpected mechanism for sound production. Much remains to be learned about how this small animal achieves such remarkable claw closing speeds and produces an audible snap.

137-4 KALLAL, RJ*; MOORE, AJ; HORMIGA, G; The George Washington University, Stony Brook University; *bobkallal@gmail.com*

The Shape of Weaver: The Evolution of Carapace Shape Disparity in Orb-Weaving Spiders (Arachnida: Araneae: Araneidae)

Orb-weaving spiders have long been recognized to show substantial variation in body size, both within and between species. Within species, orb-weavers exhibit one of the most extreme examples of sexual size dimorphism in the animal kingdom, with females often orders of magnitude longer and more massive than conspecific males. Although inter- and intraspecific variation in orb-weaving spider body size is a well-studied phenomenon, body shape variation - and the potential role of allometric influences on body shape - remain largely unexplored. Here, we use geometric morphometric methods to quantify differences in carapace shape among members of the speciose, cosmopolitan orb-weaving spider family Araneidae, and test several hypotheses concerning the evolution of shape and size dimorphism in araneids. We find that males and females occupy distinct yet overlapping volumes of morphospace, with males generally having broader carapaces and more pronounced head regions than congeneric females. Although shape disparity is not significantly different between adult males and females, female carapace shape exhibits significant phylogenetic signal whereas male shape does not, perhaps indicating that male shape is less constrained evolutionarily. We discuss results as they relate to feeding habits, vagility, and fecundity differences between the sexes.

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Role of Bilateral Odor Sampling in the Odor Source Localization Behavior of Manduca sexta

The male hawkmoth *Manduca sexta* is known to have antennal receptive fields of female sex pheromone-responsive projection neurons in the antennal lobe. There are about 80 antennal segments and the distribution of the pheromone-sensitive trichoid sensilla is greater on the middle segments of the antenna, compared to the tip and the base. In flight posture, the tips of the two antennae are ca. 2 cm apart. Using both bilateral sampling and the different receptive fields on the antennae, the moths could extract odor detailed information on spatial distribution of odor instantaneously. Importantly, the cross section of the odor plume gets narrower near the source. Taken together, it could be suggested that the *M. sexta* could use bilateral sampling strategy to locate the odor source more efficiently. In order to test this hypothesis, we studied the odor plume tracking behavior of *M. sexta* with varying length of antennal segments. For this study we used moths with 10, 20, 40 and 80 (fully intact) bilateral antennal segments. Once surgically removed the cut antennal segments were glued back onto the intact antennal segments, to restore the input from the Johnston's organ at the base of the antenna. Moths with intact antennae were successful in finding the odor source (97%, n = 37). Moths with 40 antennal segments, i.e., 50% intact antenna, performed well as intact controls (91%, n = 24) in locating the odor source. Fewer of the moths with 20 & 10 antennal segments (n = 15 & 11) (i.e., less than 50% of their functioning olfactory sensillae) succeeded in locating the odor source and exhibited great difficulty maintaining contact with and tracking the odor plume. The reduction in spatial resolution could have effected their inability to track and locate the odor source.

124-5 KAMRAN, M*; POLLOCK, A.M.M; DITTMAN, A.H; NOAKES, D.L.G; Oregon State University, Corvallis, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA, Oregon State University, Corvallis & Oregon Hatchery Research Center, Alsea; *maryam.kamran@oregonstate.edu*

Use of behavioral assays to select odorants for olfactory imprinting to improve homing in Pacific salmon

Chemoreception provides animals with ecologically relevant information about their environment. Aquatic habitats are complex sensory environments, in which reliance on chemical cues can be advantageous as an organism's reliance on other sensory modalities may be diminished. Olfactory cues provide animals with information such as the presence of a predator or location of resources such as mates and prey. Olfactory guided behaviors can also be important for habitat recognition and homing behavior(s). Anadromous salmonids exhibit natal homing, where adults return to their natal tributaries in freshwater to spawn. This homing behavior is impressive in both its spatial and temporal scales with adults travelling over hundreds of kilometers after several years at sea. Adult homing is governed by olfactory recognition of chemical cues associated with their home stream that juvenile salmon learn as they migrate downstream. While research has demonstrated that olfactory cues are critical for ensuring successful homing in adults, the identity of these chemical odorants remains largely unknown. We conducted a series of odor conditioning behavioral assays using juvenile Chinook salmon to evaluate the olfactory learning of candidate odorants for imprinting within hatcheries.

S8-10 KANE, EA*; COHEN, HE; MARSHALL, CD; GA Southern University, TX A&M University, Galveston; *ekane@georgiasouthern.edu*

Beyond Suction-Feeding Fishes: Diverse Strategies for Integrating Functional Systems During Prey Capture in Vertebrates

Two defining traits of Kingdom Animalia are the ability to move and the need to consume food. However, many animals use whole-body movements to close the distance to prey while the jaws and mouth are used for capture and these traits may be integrated at the organismal level. This functional dependency can have negative consequences for adapting to a changing environment on both immediate and evolutionary timescales. However, despite the potential diversity of taxa, relationships between locomotor and feeding traits have been relatively unexplored. Vertebrates represent an important subset of taxa that can be used to develop common themes in our understanding of how animals rely on integrated functions. Suction-feeding fishes repeatedly coordinate approach speed with mouth movements within individuals, between populations, and across diversification events. However, whether this same pattern of coordination is common among other vertebrates is unknown. We use three case studies to examine functional integration at broader scales: 1) We compare suction and biting prey capture behaviors in guppies (*Poecilia reticulata*) to determine the effects of feeding mode on integration. 2) We analyze preliminary data from a mudskipper (*Periophthalmus barbarus*) feeding above and below water to determine the effects of the media on integration. 3) We re-analyze published prey capture data from cetaceans to determine the effects of major evolutionary transitions on integration. Together, these analyses provide new insights into how functional systems are integrated, as well as the adaptability of integration given significant evolutionary changes in one or more underlying functional systems.

91-1 KARAKAS, F*; MAAS, AE; MURPHY, DW; University of South Florida , Bermuda Institute of Ocean Sciences; *ferhat@mail.usf.edu*

Sea Butterfly Swimming: The effect of shell shape on pteropod kinematics and hydrodynamics

Sea butterflies, also called pteropods, are small, holoplanktonic marine snails with a shell composed of aragonite, a form of calcium carbonate that is sensitive to ocean acidification. Sea butterflies swim by flapping their highly flexible wing-like appendages. Pteropod swimming is not well studied but is important for diel vertical migration. Further, their negatively buoyant shells and pelagic lifestyle require an efficient use of energy. Previous studies show that the swimming hydrodynamics of *Limacina helicina*, a polar pteropod with a spiral shell, is similar to tiny insect flight aerodynamics and that unsteady lift generation techniques and forward-backward pitching are key features. However, swimming by diverse pteropod species with different shell shapes has not been examined. We present measurements of *Cuvierina columnella*, a warm water species with an elongated non-spiral shell collected off the coast of Bermuda. With a body length of 9 mm, wing length of 4.6 mm, mean chord length of 3.3 mm, wing beat frequency of 5 Hz, and mean swimming speed of 35 mm/s, these organisms swim at a body-based Reynolds number of approximately 300, a regime in which both inertial and viscous forces are important. Swimming kinematics acquired via a high speed stereophotogrammetry system reveals that the elongated shell correlates with reduced body pitching and that the wings bend approximately 180 degrees in each direction, overlapping at the end of each half-stroke. Time resolved two-dimensional flow measurements collected with a micro-PIV system show leading edge vortices present in both power and recovery strokes. Interactions between the overlapping wings and the shell also likely play a role in force generation.

122-3 KARAN, EA*; ALFARO, ME; Univ. of California, Los Angeles; *ekaran@g.ucla.edu*

Evolution of False Eyespots in Butterflyfishes: Testing Eye Camouflage and Mimicry as Anti-predator Adaptations

Many species of butterflyfish (Chaetodontidae) exhibit false eyespots (circular regions with dark pigment on the posterior body) but the factors underlying the phylogenetic distribution of this trait remain poorly understood. False eyespots are hypothesized to play a role in predator avoidance and may function to distract predators away from the true eye and head to the posterior of the body to facilitate escape. False eyespots are also thought to play a role in mitigating aggression from conspecifics in some species. Concealment of the eye, most commonly by a vertical stripe, is thought to camouflage the eye from predators, although alternative hypotheses suggest that patterns like eye bars may play a role in reducing glare. Eye coverage commonly co-occurs with false eyespots and the two patterns are hypothesized to complement each other in reducing the conspicuousness of the true eye. We assembled a phylogeny for 95 species of butterflyfish and scored each for the presence/absence of eyespots as well as a suite of other traits related to body coloration and ecology. Comparative analyses in BayesTraits revealed a significant association between false eyespots and eye coverage thus supporting the hypothesis that false eyespots have evolved to distract predators from the true eye. A comparative phylogenetic approach was used to test how color patterns evolve to minimize predation, providing a framework for studying how different factors shape color pattern diversity across fishes.

88-4 KASOJU, VT*; NGO, T; FORD, MP; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*

Clap and fling with densely bristled wings

Flight-capable miniature insects (size under 1 mm), such as thrips and fairyflies, often have wings with long bristles on the fringes. Flapping flight at such small scales is challenged by large viscous forces on the wings, characterized by Reynolds number (Re) on the order of 10 or lower. These insects use large stroke amplitudes that result in wing-wing interaction (clap and fling). Previous studies have shown that wing bristles can lower drag forces experienced during clap and fling. However, the role of the number of bristles on clap and fling aerodynamics has not been previously examined. Our forewing image analyses of about 40 species of thrips and fairyflies showed substantial variation in the total number of bristles and aspect ratio (AR) of the wing, in the range of 50-120 and 1.3-5, respectively. We experimentally examined the role of number of bristles and change in AR on force generation and leakiness of flow through the bristles. A dynamically scaled robotic model mimicking clap and fling mechanism was used to comparatively test bristled wing models with varying number of bristles at Re of 10. Non-dimensional lift and drag coefficients were estimated from strain gauge measurements of time-varying forces. The results showed that with increase in number of bristles, both lift and drag force coefficients increased. The effect of varying the number of bristles and AR on leakiness will be discussed.

P3-47 KASSNER, Z*; MUIJRES, F.T; RIBAK, G; Tel Aviv university, Israel, Wageningen University & Research, The Netherlands; *zivkassner@gmail.com*

Wing kinematics during sideslip maneuvers in damselflies

Blue-tailed damselflies (*Ischnura elegans*) tend to navigate through dense vegetation and catch flying prey while aloft. To track an oscillating target, they tend to fix their body orientation in space and fly sideways. The ability to separate heading and flight direction may aid for gaze stabilization and visual tracking of objects that move over a stationary panorama. Here, we analyzed the wing kinematics during sideways flight to unveil how four-winged damselflies coordinate wing motions to achieve controlled sideslip. Free-flying damselflies were filmed chasing an artificial target that oscillated laterally 6 cm, at 2 Hz. During the sideslip maneuver (e.g., flying sideways to the left and then to the right with little changes in body yaw), the left forewing consistently reached a more mediocaudal and a higher position above the body's horizontal plane. It also had a higher flapping amplitude, compared to the contralateral forewing. Maneuvering sideways in the opposite direction resulted in a mirror-image of the above asymmetry. No significant differences were observed in wing pitch, stroke plane angle and wingbeat frequency between the four wings throughout the maneuver. We suggest that other than enhancing maneuverability, controlling the fore- and hind wing separately improves objects tracking by improving gaze stability. Our kinematic analysis shows a mechanism that damselflies use to execute a complex maneuver that we believe, enhances the ability to track moving objects. Revealing the mechanism that allows four-winged insects to produce the sideslip maneuver provides a better understanding of the evolution of insect flight apparatus. It can also aid in the design of biomimetic drones that can execute complex maneuvers without compromising visual information.

127-1 KATIJA, K*; AOKI, N; HARNED, A; MUSHEGIAN, N; DANIELS, J; OSBORN, K; Monterey Bay Aquarium Res. Inst., Moss Landing, Cornell University, Cornell, NY, George Washington University, Washington DC, University of California, Berkeley, Smithsonian National Museum of Natural History, Washington DC; *kakani@mbari.org*

Locomotion in tomopterids: How do these gelatinous, holopelagic worms swim?

Tomopterids are globally distributed, highly motile midwater polychaetes with an unusual body form. They have a gelatinous body with no internal separation of segments, large paddle-like lateral appendages (parapodia), and only a single pair of bristles (internal, acicula) at the anterior. These morphological differences distinguish tomopterids from all other polychaetes, and based on generalized models of polychaete swimming, suggest that tomopterids are slow swimmers incapable of sustained fast swimming. However, in situ observations from remotely operated vehicles (ROVs) indicate otherwise. We collected 13 tomopterids representing six species ranging in size from 1 to 10 cm (between 440 and 1083 m depths) using ROV *Doc Ricketts*, and transferred them to filming vessels on board R/V *Western Flyer*. Using high-speed video, and subsequent digitization of 52 features on each individual using DLTdv, we find that (1) swimming is accomplished using a combination of metachronal paddling of parapodia and the propagation of an anteriorly directed body wave, and (2) paddling uses a combination of sinusoidal and sequential rowing behaviors to maximize the difference between thrust and drag during power and recovery strokes. Our results provide valuable insight into kinematics of tomopterid worms with potential applications for soft robotics and bio-inspired design.

71-6 KAUSHIK, P K*; RENZ, M; OLSSON, S B; National Centre for Biological Sciences, Bengaluru, Hochschule, Bremen; *pavan@nice.ncbs.res.in*

MultiMoVR : MULTI MOdal Virtual Reality arena for flying insects

All motile organisms need to identify and locate objects in complex natural environments. Often, single sensory modalities are ambiguous and organisms rely on multiple modalities. For example, most flying insects rely on vision, wind and odour cues to find distant objects. But our understanding of multimodal sensory integration has been limited due to the lack of appropriate tools capable of probing these modalities dynamically while still providing relevant naturalistic stimuli. To tackle this, we have built a multimodal virtual reality arena for tethered flying insects, which allows the user to independently and dynamically manipulate visual, mechano and olfactory inputs. The arena has a high refresh rate, panoramic display, directional airflow and a high-frequency odour delivery apparatus. Closed loop feedback shapes the animal's sensory experience based on its motor output. Using this, we can provide landscapes with scale and perspective, dynamic windscapes, and flux-based odourscapes to understand insect behaviour in response to multisensory input. We observe that tethered insects fly in the VR to virtual objects, make use of motion parallax, estimate distances, perceive wind direction and velocity and also orient to virtual odour sources. The arena has a modular design using off the shelf parts and can be self-assembled at a fraction of the cost of current VRs available in the market. We hope that this system will encourage a new generation of researchers who will be able to use this technology to better understand how organisms make decisions in complex environments.

P1-245 KAWAHARA, AY*; PLOTKIN, D; MEUSEMANN, K; TOUSSAINT, EFA; ESPELAND, M; DONATH, A; FRANCE, G; FRANDSEN, P; ZWICK, A; BARBER, JR; MISOF, B; BREINHOLT, J; University of Florida, University of Freiburg, Zoologisches Forschungsmuseum Alexander Koenig, Brigham Young University, Australian National Insect Collection, Boise State University, RAPiD Genomics; *kawahara@flmnh.ufl.edu*

Evolutionary history of butterflies and moths

Butterflies and moths (Lepidoptera) are a mega-diverse order of insects with nearly 160,000 described species. They are ecologically important as pollinators, are often pests to agriculture, serve as models for many different scientific disciplines, and are key indicators of environmental change, but a robust phylogenetic framework for the order is lacking. Here we present the first comprehensive, dated evolutionary tree of butterflies and moths, which was constructed based on a dataset of 2380 orthologous loci and 25 non-redundant, carefully assessed fossils. Our results show that the origin of Lepidoptera is ~295.6 ± 17.3 Ma, considerably older than previously believed. We analyzed the dataset using different datasets and dating schemes, our results conclusively show that the majority of lepidopteran lineages diversified in the Cretaceous. We test correlations to two central co-evolutionary hypotheses, the postulated synchronized timing of Lepidoptera with angiosperms and the postulate that moth ultrasonic hearing organs originated in response to bats, in the early Paleogene. Our results reveal that angiosperm-feeding lepidopteran lineages may have originated largely in synchrony with the earliest flowering plants, but the evolution of hearing organs in Lepidoptera predates the origin of insectivorous bats. The early rise in hearing organs suggest that these morphological structures had a different function in the Cretaceous and were only later co-opted as an anti-bat strategy during the Paleogene.

P2-161 KAWARASAKI, Y*; TEETS, NM; PHILIP, BN; POTTS, LJ; GANTZ, JD; DENLINGER, DL; LEE, RE; Gustavus Adolphus College, University of Kentucky, Miami University, Hendrix College, The Ohio State University, Miami University; *ykawaras@gustavus.edu*

Characterization of Drought-Induced Rapid Cold-Hardening in the Antarctic Midge, Belgica antarctica

Survival of the Antarctic midge, *Belgica antarctica*, on the terrestrial habitats of the Antarctic Peninsula is promoted, not only by the adaptation to tolerate prolonged exposures, but also by their ability to respond to unpredictable changes in their environments. Rapid cold-hardening (RCH) describes the extremely swift acclimatory response of insect that occurs within minutes to hours. Most traditionally, the RCH response is induced by a brief exposure to mildly-low temperatures. However, a similar rapid acclimatory response can also be elicited by an exposure to drought. In this study, we characterized this drought-induced RCH response in larval *B. antarctica*. Compared to fully hydrated larvae, those desiccated at various relative humidity (R.H.) conditions for 2 h had a significantly greater survival to freezing at -14 °C by ~50%. Although the amount of water larvae lost varied between 4%-16%, all treatments were equally effective in eliciting the protective response against freezing stress, and its induction was evident within 30 min of desiccation at 85 or 0% R.H. conditions. Interestingly, the RCH protection induced by desiccation persisted after larvae were allowed to recover a significant portion of the lost water. Our results indicate that larval *B. antarctica* are highly sensitive to desiccation stress, capable of swiftly initiating physiological changes in response to a small reduction in their body water content. Supported by NSF grants PLP-1341385 and PLP-1341393.

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Using Simulation Studies to Determine Phylogenetic Effect on the Evolution of Dental Material Properties in Gnathostomes

Sample size and phylogenetic signal are important and related factors in phylogenetic comparative evolutionary analyses; however, methods for assessing minimum taxonomic resolution are currently lacking. Previously, we have measured hardness and elastic modulus values in enamel and orthodentine from a broad sample of Gnathostomata. The distribution of these values demonstrated a lack of phylogenetic signal, potentially due to small sample size given the longevity of the clade. Here we tested whether low phylogenetic signal is robust to increased sampling using paired (non-randomized and randomized) simulation studies. In the first simulation, genus-rank sister taxa of represented species were added to the phylogenetic tree and assigned simulated material properties derived from the previously measured values of their congeners. In the second simulation, added taxa were instead assigned material properties randomly from a distribution of the entire materials dataset with bootstrap resampling. Both simulations were performed for 200 iterations, from which phylogenetic signal was estimated. Analysis of the simulations identified an increase in phylogenetic signal for both hardness and elastic modulus of dental tissues at higher levels of taxonomic representation, suggesting that additional sampling is necessary to elucidate underlying evolutionary processes. Further analyses should consider the needs of robust sampling to ensure that the relationships between evolutionary relatedness, dental materials, and diets can be meaningfully addressed.

73-7 KéVER, L*; BASS, AH; PARMENTIER, E; CHAGNAUD, BP; Université de Liège, Liège, Cornell University, Ithaca, Ludwig-Maximilians-University Munich, Planegg; *loic.kever@uliege.be*

A Common Neural Substrate for Sonic and Electric Signaling in Synodontid Catfish

Depending on the species, synodontid catfish produce swimbladder sounds, electric organ discharges (EODs), or both using the protractor muscle that is connected to the swimbladder via a bony plate. Neuronal modifications underlying the ability of this muscle to generate sonic and/or EOD signals are virtually unknown. Therefore, we performed a multidisciplinary comparison between a sound producer and an EOD producer. Notably, the tonal swimbladder sound of *S. grandiops* and the EOD burst of *S. nigriventris* had similar temporal and spectral features. The oscillation rate, for example, was very high (at least 100 Hz at 26±1°C). Tract tracing experiments following dextran biotin or neurobiotin labeling of the protractor nerve(s) revealed the same motoneuron and premotoneuron pools in both species. Transneuronal neurobiotin labeling of premotoneurons implied extensive gap junctional coupling throughout the premotor-motor network. Neurophysiology showed that motoneuron action potential firing depended on strong current injection in both *S. grandiops* and *S. nigriventris* (1163±461 pA and 431±322 pA, respectively). These neuronal features, among others, most likely promote highly synchronized motoneuronal activation which is required to produce high frequency tonal sounds and EODs. Our results suggest that, at least in synodontid catfish, the ability to be either sonic or electrogenic does not require extensive modifications at the level of the neural circuitry. Research support from F.R.S.-FNRS (LK) and NSF (AHB).

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Comparative Morphology of the Forelimb and Pectoral Girdle in Forward-burrowing Frogs

Anuran locomotor strategies are diverse and include saltation, swimming, walking, climbing, and burrowing. Burrowing has many benefits for frogs: predator avoidance, exploitation of novel food stores, and (especially for desert-dwelling frogs) access to a moist and cool environment. This behavioral strategy is widely convergent across anuran phylogeny—from basal groups like Rhinophrynidae to higher groups like Hemisotidae. Within burrowing frogs, there are two main burrowing strategies: head-first burrowing and feet-first burrowing. The majority (95%) of burrowing anurans dig feet-first, such as *Scaphiopus*, *Breviceps*, and *Pelobates*. While front-first burrowing is less common, it has evolved independently at least seven times across Anura. These forward-burrowers tend to be more specialized for life underground. Some of their adaptations include a reinforced rostrum, ossified sternum, enlarged forelimb retractor muscles, and robust forelimb and pectoral girdle bones. Using CT data generated through the oVert Thematic Collections Network, this project will (1) quantify shape variation in the humerus, coracoid, and scapula of burrowing taxa with 3D morphometrics, (2) visualize the muscular anatomy of the pectoral girdle with DiceCT techniques, and (3) identify potential front-first burrowing species based on their pectoral anatomy. This work also provides a framework for predicting locomotor modes in taxa for which the natural history is poorly known.

P1-120 KEER, SA*; PRADO, M; MAY, C; MCMENAMIN, S; HERNANDEZ, LP; KEER, Stepha; The George Washington University, Boston College, Boston College; *skeer@gwu.edu*

Developing a zebrafish model to investigate the role of thyroid hormone in proper mineralization of ear ossicles

Thyroid hormone plays an important role in mineralization of the skeleton throughout development and maintenance of mineralization into adulthood. Hypo- and hyperthyroidism lead to lack of mineralization and hypermineralization respectively, both of which can lead to long-term issues such as increased fracture risk and impaired functionality of bones. Indeed, hypothyroidism has been associated with anatomical defects within the middle ear of mammals, although the functional implications of these skeletal abnormalities have not been investigated. Here we use the zebrafish as a model to investigate the role of thyroid hormone in proper mineralization of several cranial features. Middle ear ossicles in mammals are derived from the hyomandibula and quadrate that support the jaws within fishes. In contrast, Weberian ossicles that characterize Ostariophysan fishes (rendering them hearing specialists) are derived from ribs and vertebral elements. Here, we investigate patterns of mineralization in both the hyomandibula and quadrate as well as the tripus, a key Weberian ossicle. These data are used in the development of a model system to evaluate morphological patterns of mineralization in both homologues of mammalian middle ear ossicles as well as ostariophysan Weberian ossicles. Functional hearing tests on these thyroid-disrupted zebrafish will ultimately be performed to determine the specific functional consequences of these improperly mineralized bones. The fact that Weberian ossicles are functionally analogous to the ossicles of the mammalian middle ear will allow us to hypothesize how mineralization defects may affect human hearing.

46-4 KEER, SA*; COHEN, K; MAY, C; MCMENAMIN, S; HERNANDEZ, LP; The George Washington University, Boston College, Boston College; *skeer@gwu.edu*

Using a thyroid-disrupted zebrafish model to investigate the evolution of cypriniform novelties

Cypriniformes is a diverse group of freshwater fishes characterized by trophic novelties that include kinethmoid-mediated premaxillary protrusion and pharyngeal jaws formed solely from greatly hypertrophied 5th ceratobranchials. The hypertrophied 5th ceratobranchial has teeth ankylosed to it and since upper pharyngeal jaws are lost fish process food against the basioccipital. While investigating the skeletal anatomy of thyroid-disrupted zebrafish we identified profound anatomical changes to both the pharyngeal jaws and those structural elements associated with premaxillary protrusion. Thyroid hormone regulates tooth number; hypothyroid pharyngeal jaws had significantly more teeth, while hyperthyroid jaws had significantly fewer teeth. The anterior jaws, and the resulting kinethmoid-mediated premaxillary protrusion, were also strongly affected thyroid hormone. The kinethmoid is a sesamoid bone that sits ventral to the ascending process of the premaxilla and dorsal to the maxilla and has been shown to play a vital role in cypriniform jaw protrusion. In the hypothyroid zebrafish, the kinethmoid fails to ossify properly and lacks the characteristic lateral wings and dorsal process, as does the ascending process of the premaxilla. In the hyperthyroid zebrafish, the kinethmoid is hyperossified and improperly shaped as a result. Thyroid hormone therefore normally regulates the proper development of these feeding structures, and modulation of thyroid hormone likely gives rise to some of the anatomical differences observed both within Cypriniformes and outside of it. Understanding how the modulation of thyroid hormone changes these bones, and thus their ability to function, may lend insight into how they may have evolved.

3-8 KEISER, CN*; SALTZ, JB; RUDOLF, VHW; University of Florida, Rice University; *ckeiser@ufl.edu*

Behavioral trait variation mediates the relationship between genetic diversity and disease

The relationship between population diversity and the severity of disease dynamics is a highly debated but poorly resolved theme in infectious disease ecology. Increased genetic diversity within a host population may reduce the severity of epidemics because diverse populations may harbor more resistant or resilient individuals. However, genetic diversity per se may not alone alter population-level effects of disease, as host behavioral phenotypes play an integral role in disease defenses and genetically diverse populations are not always phenotypically diverse. We identified genotypes of the fly *Drosophila melanogaster* that did not differ in susceptibility to the generalist entomopathogenic fungus *Metarhizium robertsii* but varied in a suite of behavioral traits that alter infection risk. We then produced populations that contained one of five different genotypes, mixtures of three genotypes that exhibited similar behavioral phenotypes, or mixtures of three phenotypically diverse genotypes. Populations were exposed to a 24hr pathogen pulse, and then allowed to interact naturally on pathogen-free food patches for 20 days where we measured mortality daily compared to pathogen-free controls. We found that mixed-genotype populations experienced greater mortality compared to monotypic populations only when made up of phenotypically diverse individuals. That is, genetic diversity alone did not alter disease dynamics, but phenotypically diverse populations died more rapidly, potentially because the presence of diverse behavioral phenotypes may increase the number of ways in which individuals can become infected and transmit infectious agents to conspecifics.

51-3 KELLEHER, JM*; MYKLES, DL; Colorado State University; *jameskelleher75@gmail.com*

Characterization of the molt cycle of the cherry shrimp, Neocaridina davidi

The freshwater red cherry shrimp *Neocaridina davidi* (incorrectly identified as *N. denticulata*) has been proposed as a new model organism for crustacean biology due to its ease of culture, high reproductive capacity, abbreviated intermolt periods, and tractability for transgenic studies. Prior work on this species is sparse and rife with taxonomic confusion, particularly regarding its molting ecology. To form a basis for studies on crustacean molt regulation, a simple and rapid staging method in live *N. davidi* was developed. Observing setagenesis through the transparent cuticle proved to be the simplest way to directly monitor molt cycle stages. The outer uropods of adult males were imaged daily through a complete molt cycle. Progressive changes in the structure of the developing cuticle and setae delineated intermolt (C4), premolt (D0, D1, D2, & D3,4), and postmolt (A, B) stages. The approximate interval between consecutive molts was 10 days at 23 ˚C. Rapid growth was associated with a short intermolt stage of ~5 days; the durations of the postmolt and premolt stages were ~1 day and 4 days, respectively. Future studies will quantify hemolymph molting hormone (ecdysteroid) titers to confirm the molt stages. Immunohistochemistry will be used to identify the *N. davidi* Y-organ, which synthesizes and secretes ecdysteroids. Precise staging is essential for applying transcriptomic and transgenic tools to *N. davidi* for the study of the genetic mechanisms that regulate molting in decapod crustaceans. Supported by NSF (IOS-1257732).

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Gopherus polyphemus behaviorally discriminate conspecific chemical cues from other environmental chemical cues

Gopher tortoises are social and have been shown to behaviorally respond to intraspecific chemical cues in their environment, discriminating potential mate-choice cues from other scents. Studies have shown that certain chemicals from chin gland secretions can elicit combat behaviors in male tortoises when placed on inanimate objects. Likewise, other studies of tortoises have shown that olfactory investigation is increased when chin gland secretions are present at burrows and that tortoises are able to recognize familiar from unfamiliar conspecifics. Yet, no study has examined social behaviors, such as head-bobbing, in gopher tortoises towards only a chemical presentation of chin gland secretions. In this study, using a paired design presenting cotton swabs of pooled male gopher tortoise chin gland secretions vs. controls (acetone & strawberry, in two separate experiments), we found that tortoises of both sexes (p=0.68) were 9 times more likely to sniff chin gland secretions than acetone (p=0.0004), and also, performed grouped behaviors (i.e., sniffing, eating, biting, & head bobbing) preferentially towards the chin gland swab (p=0.0003). In the second experiment using chin gland secretions vs. strawberry, we found that tortoises also discriminate between chemical cues through different head bobbing vs. nodding behavior. For example, towards the chin gland treatment, only dominant head bob displays (>10 seconds) were observed similar to courtship (p=0.056), whereas towards the strawberry treatment, only brief (~2 seconds) olfactory nods or head extensions (p=0.03) were observed. Differential head movements suggest discrimination of olfactory signals, in which chin gland cues elicit social awareness but strawberry cues only elicit olfactory awareness.

P2-37 KELLEY, MD; CAGLIANONE, J*; MENDONCA, MT; Auburn University; *mdk0014@auburn.edu*

Gopher tortoises behaviorally utilize UV signals in their external environment

Most chelonians are slow-moving, herbivorous vertebrates that rely on brightly colored plants to obtain their nutritious requirements. As a result, coevolution with their plant foods has been suggested as a potential cause for a trade-off between visual and olfactory acuity (i.e. influencing the ability to find food items at close vs. long range by using both color and smell). While recent studies have emphasized the chemosensory abilities of reptiles, some studies have also shown that in addition to specialized chemosensation through large olfactory bulbs & the vomeronasal organ, many reptiles may also have a 4th cone in their retina to be able to see in the ultraviolet spectrum of color as well (e.g., red-eared sliders) and behaviorally prefer UV signals. In this study, we assessed UV behavioral preference in gopher tortoises (*Gopherus polyphemus*) through the use of cardboard discs in a paired choice experiment [Treatment 1: orange disc with spectra peak between 700-850 nanometers (nm) and Treatment 2: orange disc with spectra peak between 700-850 nm and UV peak between 200-300 nm]. Because visual recognition is immediate, initial contest analysis via chi-squared analysis indicated a significant effect of first choice for the UV disc (p=0.004), regardless of randomized presentation to either sex. Additionally, a Poisson distribution of raw numbers of different behaviors also indicated a preference for the UV treatment (p=0.011). Finally, after performing a principal component analysis, principal component 1, including behaviors of sniffing, head extension, and biting/rubbing the disc, significantly differed in preference for the UV treatment (p=0.02), regardless of sex (p=0.1). This is the first study to indicate a behavioral preference for visual signals in the UV for gopher tortoises.

126-1 KELLY, JB; Stony Brook University; *joseph.b.kelly@stonybrook.edu*

Holobiont species delimitation in the sponge genus Ircinia

Microbiomes are quickly gaining recognition as ubiquitous and integral components of multicellular organisms whose imprints are found in the biology of their hosts. In the sponge genus *Ircinia*, evolutionary responses to host-microbial symbioses abound as *Ircinia* holobionts exhibit several hallmarks of metabolic integration including microbial genome streamlining, translocation of nutrients between the microbes and sponges, and heritability of endosymbionts. Thus, microbes in *Ircinia* hold the potential to influence the evolutionary histories of their hosts. A Caribbean member of this genus, *I. felix*, is represented by four distinct morphotypes that are regarded as putative lineages. This study tests the hypothesis that these four morphotypes constitute separate species by analyzing microbial 16S and host-derived RADseq data using tests of host-microbe co-diversification and the multispecies coalescent. As the bodies of *Ircinia* and sponges in many other clades possess few taxonomically informative characters, this approach to species delimitation provides a means to resolve species boundaries where traditional morphology-based taxonomy has fallen short.

S5-4 KELLY, Morgan*; SIROVY, Kyle; LAPEYRE, Jerome; KELLY, Morgan; Louisiana State University; *morgankelly@lsu.edu*

What doesn't bend: Environmentally responsive gene expression and measures of fitness in natural populations of the eastern oyster, Crassostrea virginica

Species responses to environmental stress have been well characterized across a broad range of taxa. Less well understood are intraspecific variations in stress responses, and how this variation correlates with fitness, both among individuals and across environments. Along the coast of the northern Gulf of Mexico, the two most important axes of environmental variation setting the distributions of benthic invertebrates are salinity and temperature. Both of these are expected to change rapidly over the coming century, with a projected 2.5˚C increase in coastal sea surface temperature and rapid changes in salinity regimes due to changes in rainfall patterns and anthropogenic alterations to coastal hydrology. These changes in the environment will have important impacts of the distributions of benthic invertebrates, most notably the economically and ecologically important eastern oyster (*Crassostrea virginica*). Here, we use comparative transcriptomics to quantify the response to salinity among experimental crosses of the eastern oyster split between low and intermediate salinities in common garden conditions for 14 months. We compare the gene expression response to metrics of fitness (growth and disease status) to identify physiological correlates of fitness across environments. Our results will help to identify which components of the osmotic stress response are adaptive in this species.

P3-39 KELSAY, TS*; SEIN, IH; DEBAN, SM; University of South Florida; *tkelsay@mail.usf.edu*
Thermal Sensitivity of Burst Swimming in Salamanders
In many biological systems, escape response affects the predator/prey dynamic. For animals in which burst speed is essential for survival, time to peak velocity is paramount. However, environmental temperature affects performance of many organismal movements. Muscle-powered movement is especially thermally sensitive in ectothermic tetrapods; therefore, acceleration of salamanders to peak velocity is expected to be significantly affected by temperature changes. Previous studies have shown, however, that some salamander species show surprisingly low thermal dependence of swimming velocity (Q_{10} ~ 1.0-1.6). We imaged several genera of salamanders swimming in a temperature-controlled basin at 7 and 17°C (±1°C) and measured time to peak velocity, peak velocity, average acceleration, as well as the frequency and amplitude of the traveling body wave. In general, thermal sensitivity of swimming acceleration and velocity were lower than that of limbed locomotion in ectothermic tetrapods that have been examined, confirming earlier studies. Frequency and amplitude of the traveling wave were significantly different across temperatures. Investigating the energetics, fluid flow and motor control of swimming would yield insight into the interestingly low temperature sensitivity that salamanders exhibit while swimming.

103-6 KENALEY, CP*; PETROSIAN, G; SANTOS-POWELL, N; ROONEY, C; Boston College; *cpkenaley@gmail.com*
No One Lambda: Propulsive Wavelength Varies with Swimming Speed and Axial Position in Rainbow Trout.
Fishes swim by generating thrust through undulatory waves that propagate rostrocaudally down the body. Although many studies have investigated the hydrodynamic and fluid-structure influences on thrust production, relatively few have focused on the axial behavior of the fish body during swimming, especially over a range of biologically relevant speeds and beyond trailing-edge amplitude and frequency. The goal of this study was to revisit the relationships between propulsive wavelength and swimming speed and propulsive wavelength and body axial position. To this end, we performed flume-based experiments on rainbow trout (*Oncorhynchus mykiss*) swimming at 40 discrete speeds, ranging from 0.5-6.0 BL/s. Using a novel semi-automated tracking system implemented in the R computing environment, we amassed a dataset that includes over 80 thousand separate waveforms from five individual fish and this range of speeds. Our conclusive results indicate that: (1) undulatory wavelength increases as it passes through the body and (2) that this parameter has a non-linear, idiosyncratic relationship with swimming speed, both increasing and decreasing as much as 40% over different ranges of speed. Taken together, these results underscore the importance of both passive and active elements of the fish musculoskeletal system in modulating propulsive dynamics and that fishes may modulate body stiffness to optimize thrust under variable speed conditions.

P1-220 KENNEDY, J/GC*; LEARY, C/J; Univ. of Mississippi; *jgkenned@go.olemiss.edu*
The role of reproductive interference and endocrine stress in the decline of native green treefrogs following Cuban treefrog invasions
Invasive species are a leading cause of global amphibian declines. In many cases, how invasive species negatively impact native amphibians is well established, but in other cases these processes remain enigmatic. For example, the introduction of Cuban treefrogs, *Osteopilus septentrionalis*, in the southeastern United States is linked to the decline of native green treefrogs, *Hyla cinerea*, but there is little evidence that predation, competitive exclusion, or transmission of pathogens are contributing factors. Here we examine how reproductive interference and endocrine stress potentially contribute to the negative impacts of invasive Cuban treefrogs on native green treefrogs. We hypothesize that reproductive interference plays a central role in the decline of native green treefrogs following Cuban treefrog invasions because the acoustic communication systems of these species overlap in a way that is predicted to stimulate chronic elevations in circulating glucocorticoids in green treefrogs. For example, male Cuban treefrogs produce advertisement calls possessing similar spectral and temporal features as the aggressive calls of male green treefrogs. Male green treefrogs produce aggressive calls during intraspecific vocal contests and hearing these calls stimulates the production of corticosterone (CORT) in vocal contest losers, which suppresses reproductive behavior. We will present preliminary data from vocal playback experiments examining how the acoustic courtship signals of Cuban treefrogs affect the endocrine physiology of native green treefrogs.

79-5 KENNEDY, JH*; SIENKIEWICZ, R.; FISH, F.; GOLDBOGEN, JA; POTVIN, J; Saint Louis University, West Chester University, Hopkins Marine Station-Stanford University; *john.kennedy@slu.edu*
Computational Fluid Dynamics Study of Baleen Whale Drag
By including the largest vertebrates to have ever lived, baleen whales (Mysticeti) represent a group of highly-streamlined marine mammals that has achieved efficient, low-drag locomotion. High swimming efficiency by cetaceans has been confirmed, so far, by estimates based on flat-plate drag empirically corrected for body fineness ratio effects that increase drag via the turbulent wake. As useful as it may be, the approach is silent on the role of body shape and size in determining the relative importance of viscous friction, versus the pressure drag that result in the near-wake. We present the results of a Computational Fluid Dynamics (CFD) study of the flows and drag generated by several mysticete species, including 11 and 22m blue whales (*Balaenoptera musculus*), 14m humpback (*Megaptera novaeangliae*), 9m minke (*B. acutorostrata*) and 12m grey (*Eschrichtius robustus*). The simulations and analysis were carried out with the SC/Tetra commercial software. The whale models were obtained from the 3D-scanning of anatomically realistic figurines. The results, which are specific to rigid (gliding) bodies, were corrected with a new semi-empirical tail-heaving drag factor accounting for active swimming effects. It is shown that for these swimmers, viscous friction is the dominant source of drag (about 75%) over pressure drag (25%); that total drag per body area is rather insensitive (down to about 10-15%) to body shape and tail vertical taper within and across species; and that the unsteady drag generated by the caudal peduncle effectively doubles the drag coefficient, in comparison to rigid body drag.

53-8 KENNY, MC*; CRANDALL, CL; SINCLAIR, BJ; SOCHA, JJ; Virginia Tech, University of Western Ontario, Virginia TEch; *mck66@vt.edu*

Effects of environmental temperature on viscosity of Manduca sexta hemolymph

Temperature influences many aspects of insect physiology, impacting behavior and survival. Recently, we found that insect hemolymph viscosity is also temperature dependent, showing a 6.4x change from 0 to 45°C in *Manduca sexta* larvae. As poikilotherms, insects experience a wide range of internal temperatures, suggesting that their circulatory system must accommodate a broad range of viscosities. Changes in hemolymph viscosity could significantly affect the dynamics of circulatory flows. Insects respond physiologically to acclimation at different temperatures with mechanisms such as release of proteins or fatty acids, thereby affecting hemolymph composition, but it is unclear if they also affect viscosity. Here we ask, does rearing temperature affect the viscosity of insect hemolymph? We measured viscosity of hemolymph from *Manduca sexta* larvae reared in three different temperature regimes: 10/15 (cool), 20/25, (room) and 30/35 (warm) °C, with 10/14 hour night/day cycles. A cone-and-plate viscometer attached to a circulating bath measured viscosity at 5, 15, 25, and 35°C. Cell diameter, volume, viability, and circularity of hemolymph was measured via a ViCell cell counter. Viscosity values were equivalent for all rearing conditions when measured at 25 and 35°C, but hemolymph viscosity decreased for warm and cool-reared insects at 15°C and for cool-reared insects at 5°C. In addition, while there are no differences in cell volume between rearing conditions, average cell diameter was significantly higher in cold-reared insects. These data suggest that compositional changes of hemolymph in response to temperature may also affect viscosity in insects. Supported by NSF 1558052.

P2-281 KENNY, NJ*; RIESGO, A; The Natural History Museum, London; *n.kenny@nhm.ac.uk*

Evolution on Ice: 'Omic insights into Molecular Adaptation in Antarctic Sponges

Animals in the Antarctic seas have adapted to some of the most challenging conditions found anywhere on Earth. Temperatures ranging between 0 and -1.8°C and a food supply which fluctuates widely render their survival difficult. Nevertheless, species have found the means to thrive in such conditions. Sponges are particularly important members of Antarctic ecosystems, but to date our knowledge of how they endure these temperatures is limited at best, especially at a molecular level. We aim to identify the mechanisms by which sponges have adapted to such extreme environments by contrasting congeneric species pairs adapted to vastly differing thermal environments. These aims are being accomplished using transcriptomic and genomic sequences from genera within the Demospongiae. The chosen genera are abundant in the Antarctic, Caribbean and Mediterranean, and play essential roles in the benthic ecosystems in which they are found. Particularly, we have sequenced multiple transcriptomes from 10 target species, as well as the genomes of *Mycale acerata* and *Mycale laevis*, and are supplementing our "omic" work with targeted in situ and functional experiments. Using this data, we have performed a number of tests for selection (particularly in Hyphy/CODEML) and identified genes with multiple lines of evidence for positive selection, including a number of phylogenetically well-conserved "housekeeping" genes. We have also analyzed differential gene expression and content. With this data, we can state which genes are vital in cold conditions, and when adaptive molecular mechanisms have been used broadly, convergently, or in vastly varying ways across sponge and animal phylogeny.

P3-171 KEPAS , ME*; VIRGIN , EE; HUDSON , SB; WEBB, AC ; FRENCH , SS; Utah State University ; *megenkepas@gmail.com*

Sex Differences in the Metabolic Rates of Uta stansburiana in Relation to Oxidative Stress

The regulation of metabolism in response to environmental stressors is a crucial adaptation. Increased metabolic rate leads to mitochondrial production of reactive oxygen species. Here, we investigate the impact of metabolic rate on oxidative stress in the Common side-blotched lizard (*Uta stansburiana*) and compare sex differences in standard metabolic rate relative to oxidative stress. The metabolic rates of males and females may also differ significantly due to both differential energetic requirements and levels of metabolically active hormones. In this study, we measured resting metabolic rate and oxidative capacity in 53 male and 39 female wild-caught side-blotched lizards from St. George, UT. Oxidative capacity of individuals was calculated by combining measures of blood antioxidants (OXY) and reactive oxygen metabolites (d-ROMS). The oxidative index data were compared with standard metabolic measures of O2 intake and CO2 output in a climate-controlled environmental chamber. We also assessed the effect of reproductive investment (e.g., clutch size and stage) on oxidative capacity in females. From these comparisons we can better understand the sex-dependent role of physical stress on metabolism, as well as the oxidative costs of both reproductive investment and metabolic activity.

P2-90 KERNBACH, M.E.*; CASSONE, V.; MARTIN, L.B.; University of South Florida, University of Kentucky; *Kernbach@mail.usf.edu*

The Impact of Light Pollution on Melatonin Secretion in House Sparrows

Light pollution, or the presence of unnatural light at night, is a widespread yet understudied anthropogenic stressor. Although impacts of light pollution on wildlife have become apparent over the years, the mechanisms by which artificial light at night affects their physiology and behavior are not well understood. For example, avian reservoir species exposed to dim light at night exhibit decreased resistance to West Nile virus. The hormone melatonin (i.e. the "chemical expression of darkness") is secreted in darkness and suppressed in the presence of light. This indolamine coordinates daily rhythms within the body including metabolism and immune functions. Because melatonin plays such an integral role in coordinating these physiological functions, it remains a possibility that light pollution induced suppression of melatonin leads to maladies in wildlife. To investigate whether melatonin is suppressed by dim light at night, we exposed wild-caught house sparrows (*Passer domesticus) to ~6 lux light at night in captivity for 3 weeks and measured melatonin at 5 points throughout the night. This study emphasizes that light pollution can influence hormonal regulation and potentially mediate downstream circadian incoordination or physiological functions that lead to detrimental outcomes in wildlife.*

71-7 KESSLER, BJ*; YAN, L; SANKO, K; ELIAS, DO; Univ. of California, Berkeley; *benjikessler@berkeley.edu*

How do jumping spiders use visual and vibratory information to catch prey?

Animals that engage in active stalking as a predation technique need to acquire sufficient sensory information to locate, capture, and overtake their prey. Jumping spiders are day-active hunters with highly acute vision and tremorsense (the ability to detect substrate-borne vibration). They use both of these senses in conjunction (multimodally) in assessing potential mates, and they are known to be highly visual in their prey-capture tactics. However, it has not been previously demonstrated if and how they use multimodal sensory perception in prey-capture. In this study we used a lab behavioral experiment with factorial design to investigate the contribution of visual and vibratory information to a jumping spider's ability to locate and subdue prey. We also investigated the role of specific eye types in prey capture with selective eye-occlusion in a separate behavioral assay. We found that restricting light intensity reduced the probability of successfully catching prey, while restricting vibratory transmission increased the time-to-capture for successful captures. Additionally, we found that occlusion of the principal eyes caused a reduction in prey capture success that was additive with the reduction caused by light restriction. Our results show that visual information is necessary and sufficient for prey capture, but that vibratory information can play a contributory role. Furthermore, we found from our eye-occlusion experiment that principal eyes aid in prey capture but are only strictly necessary under low-light conditions. Multimodality is rarely studied in the context of prey capture, yet it may be very prevalent among active-hunting animals. These results and methods can contribute to a framework for studying the sensory ecology of prey capture in a multimodal context.

22-1 KHALIL, S*; WELKLIN, JF; MCGRAW, KJ; WEBSTER, MS; KARUBIAN, J; Tulane University, Cornell University, Arizona State University; *skhalil@tulane.edu*

Testosterone, Gene Expression, and Plasma Carotenoids Underlie Red Plumage Ornamentation in the Red-backed Fairywren

Carotenoid-based signaling is thought to be a classic example of honest signaling, in that acquiring and metabolizing carotenoids likely imposes costs and individuals expressing the most carotenoid rich signals are therefore predicted to be in the best condition. Yet the proximate mechanisms of carotenoid production remain poorly resolved, which limits our understanding of the evolutionary constraints and physiological costs associated with this widespread signaling modality. The red-backed fairywren (*Malurus melanocephalus*) provides a useful context in which to examine mechanisms underlying expression of carotenoid-based ornamentation: male red-backed fairywrens exhibit flexible reproductive phenotypes, where older individuals have high circulating testosterone and breed in red/black plumage and younger individuals have low circulating testosterone and breed in female-like brown plumage. To better understand the mechanisms that regulate signal expression, we asked if circulating carotenoid levels and gene expression of a carotenoid ketolase gene (CYP2J19) differ as a function of sex and male phenotype, and if testosterone may be regulating this expression. As predicted, red/black males had higher concentrations of circulating carotenoids in their plasma than either brown males and females. In addition, we experimentally manipulated testosterone levels in brown males, and found a relationship between testosterone and the expression of CYP2J19 in the liver. This work highlights the complex ways in which carotenoids may be used to signal quality, and how hormones, gene expression, and circulating carotenoids may underlie the production of carotenoid-based ornamentation.

P2-240 KHOUJA, S*; EDIE , S; COLLINS, K; JABLONSKI , D; University of Chicago; *safia@uchicago.edu*

Bivalves Unhinged: Hinge Morphology and Biomechanics in the Veneridae

Hinges enable bivalves to perform the critical motion of opening and closing the paired valves, while resisting shear during burrowing and predation. The diversity in hingeplates across the family Veneridae echoes the functional and morphological variety that defines this, the most diverse family in the Bivalvia (~750 extant species in 135 genera). Despite the biomechanical importance of the hinge, its complex shape has made it difficult to analyze in traditional morphometric frameworks. Thanks to our campaign to 3D scan all of Bivalvia using X-ray computed micro-tomography (microCT), we have unprecedented access to the minute details of hingeplate morphology. In particular, we focused on the toothbank (i.e. the region of the hinge containing the primary dentition in the form of the cardinal teeth). We quantified toothbank morphology by using homologous points and semilandmark curves to automatically generate surface semilandmarks on 3D scans of 150 species in 132 genera. This method allowed us to compare more distantly related and morphologically disparate taxa than a strict landmark analysis would. We used Procrustes-PCA (Principal Components Analysis) to create a morphospace of hinge shapes, within which we assessed potential effects of partitioning by taxonomic association, body size, and shell ornamentation. Our preliminary results revealed biomechanical trends among hingeplate shape, tooth placement, and tooth "topography" (the projection of the teeth above the hingeplate). Specifically, we found that these trends correlate more strongly to shell ornamentation and life habits than taxonomic groupings or shell size/outline shape. Compared to unornamented shells, highly ornamented shells have larger hinge plates with higher reliefs, and shallower burrowers tend to have thicker teeth and correspondingly wider sockets than deeper burrowers.

108-3 KHUDYAKOV, J*; STEPHAN, A; NGO, A; ABDOLLAHI, E; SANDHU, G; COSTA, D; CROCKER, D; Univ. of Pacific, Univ. of California, Santa Cruz, Sonoma State Univ.; *jkhudyakov@pacific.edu*

Fat and Fasting: Expression of Obesity-Associated Genes During Fasting in a Naturally Obese Marine Mammal

Adipose tissue is a complex energy storage and endocrine organ that regulates metabolic homeostasis via adipocyte-derived hormones (adipokines). Excess adiposity in humans is correlated with increased adipokine levels, insulin resistance, and inflammation, and is a major risk factor for metabolic pathologies. With some of the largest subcutaneous adipose stores in the animal kingdom, marine mammals may provide valuable insights into the role of adipose tissue in health and disease. Capital breeding marine mammals rely on lipid stores in blubber to sustain fasting periods associated with terrestrial breeding and migration. Northern elephant seals (Mirounga angustirostris) undergo two annual fasts during breeding and molting haul-outs, losing up to half of their fat mass over a period of 1-3 months while maintaining high circulating fatty acid and glucose levels and insulin resistance, similarly to obese humans. We examined changes in expression of genes associated with obesity in humans in blubber of fasting adult female elephant seals using quantitative PCR. Target genes included leptin, adiponectin, resistin, retinol-binding protein 4, and visfatin, among others. Normalized gene expression values were compared between early breeding, late breeding, early molting, and late molting groups using linear mixed models. Expression values were significantly different between groups and the majority of adipokine genes were upregulated in late fasting compared with early fasting seals, despite a concomitant decline in fat mass. This suggests a mechanism by which elephant seals maintain insulin resistance and lipid oxidation during fasting periods characterized by high energy expenditure, and provides insights into rapid weight gain and loss in mammals.

129-6 KIENLE, SS*; CACANINDIN, A ; COSTA, DP; MEHTA, RS; Univ of California Santa Cruz, Univ. of California Santa Cruz, Univ. of California Santa Cruz; *skienle@ucsc.edu*

Hawaiian Monk Seals Suck: Behavioral Flexibility in Feeding Strategies and Kinematics When Hawaiian Monk Seals Target Different Prey

Animals use diverse feeding strategies to capture and consume prey underwater. Many marine animals exhibit behavioral flexibility when feeding to deal with spatial and temporal heterogeneity in prey resources. However, observations of feeding events underwater are rare, so little is known about the relationship between feeding strategies, kinematic performance, and behavioral flexibility. We documented the feeding behavior and kinematics of the critically endangered Hawaiian monk seal (*Neomonachus schauinslandi*, n=7) through controlled feeding trials. Seals were fed multiple prey types (e.g., night smelt, capelin, squid, and herring) that varied in size and shape, and we used mixed effects models and multivariate analyses to examine behavioral flexibility in behavior and kinematic performance. Although Hawaiian monk seals have a skull morphology adapted for biting, seals primarily used suction feeding (91% of feeding trials) across all prey types; seals used biting less frequently (9% of feeding trials). Suction feeding was kinematically distinct from biting and characterized by shorter temporal events, a smaller maximum gape, a larger gular depression, and fewer jaw motions compared to biting. Seals showed behavioral flexibility in their use of the strategies; suction feeding was used most frequently when targeting small to medium prey, and biting was used with increasing frequency on large prey. The feeding kinematics differed between strategies and prey types, showing that seals adjusted their kinematics to particular feeding contexts. Hawaiian monk seals are opportunistic and generalist marine predators and their ability to adapt their feeding behaviors and kinematics as found in this study should allow them to target diverse prey resources.

140-5 KIKUCHI, DM*; MAEDA, M; SHIOMI, K; TANAKA, H; Tokyo Institute of Technology, Royal Veterinary College Univ. of London, National Institute of Polar Research; *kikuchi.d.ab@m.titech.ac.jp*

Fluid dynamics function of the rhinoceros auklets' horn in flying and swimming

The exaggerated morphological traits that appear in either sex in the breeding season (ornaments) have long been considered to have evolved by sexual selection. Acc ordingly, these would increase the success rate of mating. However, in some cases, it has been observed that these ornament-like traits are not likely to be related to sexual selection. One such example is the horn of the rhinoceros auklet *Cerorhinca monocerata*, a seabird species. The horn appears on the upper side of the beak in both males and females only in breeding season. Also, it has been reported that there are no differences between the sexes in the size of the horn. Hence, the horn may have a function besides affecting mating success. However, till date, no plausible function of the horn has been suggested. During the breeding season, in order to feed their chicks, both sexes of auklets fly with fish in their beaks, which would cause a substantially large drag. Thus, a preliminary computational fluid dynamics simulation study was performed, to examine the effect of the horn and prey fish on the energy cost of transport. According to the simulation, the horn negligibly increases drag during flight compared to the model without the horn. Meanwhile, with the prey in their beaks, the drag of the model with the horn was slightly less than the no-horn model. Although the mechanism of the drag reduction remains unclear, it has been hypothesized that the horn of the auklet may have a fluid dynamics function, particularly when the bird flies with fish in its beak, which potentially causes a large drag. To test this hypothesis, water tunnel experiments were conducted using 3D printed bird models, to measure the effect of the horn and prey fish on the rhinoceros auklets' flying/swimming cost of transport. The results of the drag force measurement of the models across the evaluated range of body angles and flow speeds will be reported shortly.

P1-198 KIM, GE*; ALBRIGHT, R; RITSON-WILLIAMS, R; Tufts Univserity, California Academy of Sciences, California Academy of Sceinces; *grace_e.kim@tufts.edu*

Foundational studies of Caribbean crustose coralline algae

Many coral reef restoration efforts fail to address the natural ecosystem processes necessary for the long-term persistence of reefs. Crustose coralline algae (CCA) have been shown to play many essential ecological roles on reefs including facilitating coral recruitment and contributing to reef calcification. Despite their demonstrated significance, little is known about the diversity of these algae on reefs. Understanding the systematics of CCA has largely been limited by their cryptic taxonomy which relies on specialized morphological features difficult to discern without a microscope. Here we provide an accessible morphological and molecular characterization of the Caribbean CCA, and evaluate hypotheses of CCA relationships through the phylogeny of these Caribbean species. Using the genetic marker *psbA*, we found that despite morphological similarities, *Titanoderma prototypum* is distinct from *Lithoperella atlantica*. Further, the diagnostic significance of secondary pit structures within the family Lithophylloideae (*Lithophyllum* spp. and *Titanoderma* spp.) was verified by scanning electron microscopy. We found that *psbA* was diagnostic for each species, so it can serve as a genetic barcode for Caribbean CCA and will be assembled into a database as a foundation for identifying CCA species. We will also compile these morphological details and live photographs into a guidebook that can be used by researchers to identify CCA species in the field, with the hope of furthering the study and restoration of these critical reef plants.

P2-36 KIM, J*; FUSE, M; San Francisco State University; *jenn_kim@outlook.com*

DNA methylation regulates different nociceptive responses to strong vs. mild stimuli in Manduca sexta

Nociception is the neural process that underlies responses to threatening stimuli, and is seen even in animals with the simplest of sensory systems. In a form of non-associative learning known as nociceptive sensitization, organisms respond to harmful stimuli with defensive behaviors and maintain heightened responses even in the absence of the stimuli. While the molecular mechanisms underlying nociceptive sensitization are increasingly characterized, it is unclear how conserved they are across the animal kingdom. DNA methylation (DNAm) has been shown in different species to regulate learning and memory paradigms, including nociceptive sensitization in some instances. In this study, we hypothesize that DNAm regulates nociceptive responses in the tobacco hornworm, *Manduca sexta*. We have identified putative DNAm genes in the *M. sexta* genome, and have used a behavioral assay to determine changes in the threshold force to elicit a defensive striking behavior before and after either a strong (pinch to the body wall) or mild (injection) stimulus. Vehicle-injected animals typically remain unaffected by the injection, yet become sensitized after a pinch, where subsequent testing results in a strike threshold that is significantly lower than baseline. Injecting DNAm inhibitors, RG108 and Zebularine, not only countered the decrease in threshold typically seen in sensitized animals, but also facilitated a decrease in threshold in response to the injection. These results suggest that DNAm mediates both nociceptive responses to strong stimuli and anti-nociceptive responses to mild stimuli. Methylation and bioinformatics analyses will be done to further assess these findings and identify genes that are differentially methylated in nociceptive responses.

P2-122 KIMBALL, MG*; CHRISLER, AD; GRANT, A; MALISCH, JL; St. Mary's College of Maryland, Univ. of Nevada, Reno; *mgkimball@smcm.edu*

Acute stress and glucose mobilization in Mountain Dark-eyed Juncos (Junco hyemalis)

Resource mobilization and reallocation is a major endpoint of the physiological response to acute stress. In mammals, a hyperglycemic response to acute handling stress is well characterized, however it is not consistently detectable in non-mammalian vertebrates. A hyperglycemic response to acute handling stress has been shown in some passerines including White-crowned Sparrows and White-throated Sparrows. Here we characterized the glycemic response to acute-handling stress in a breeding, free-living, population of Mountain Dark-eyed Juncos (*Junco hyemalis*) in Mono County, CA. Juncos were trapped in seed-baited potter traps at Tioga Pass Meadow from May 17 to June 20, 2018, coinciding with territory establishment and early nesting period. Blood samples were collected at 0, 15 and 30 min post-capture. We utilized a human blood glucose meter, FreeStyle Lite, to determine real-time glucose levels in the field, after previously validating this novel technique. Consistent with research in other sparrow species listed above, blood glucose levels were higher than baseline (time point zero) at 15 minutes (42.6% increase) and 30 minutes post-capture (66.7% increase). Additionally, predictors of glucose mobilization including: date, scaled body mass, fat score, hematocrit, sex, and bleed delay time were modeled using backward and forward stepwise regression. Analysis showed that Juncos mobilize glucose in response to acute handling stress and response is best modeled when scaled mass, hematocrit, and date are included as predictor variables. These results suggest that glucose mobilization capacity is influenced by measures of body condition including mass and hematocrit, and the response may fluctuate during the breeding season.

P1-165 KINDEL, M*; KöNIG, B; LOPES, PC; Chapman Univ., Univ. Zurich; *kinde108@mail.chapman.edu*

Can Peripheral Immunity of Healthy Animals Affect Social Behavior?

Social interactions are critical for the survival and reproduction of many organisms, but also carry costs, such as exposure to pathogens. Given the role played by the immune system in determining vulnerability to infections, could molecules from this system also serve a role in mediating exposure to pathogens by impacting variation in social behavior? We here test whether immune function in the blood may be associated with the propensity to seek social interactions (sociability). To do this, we studied a population of wild house mice (*Mus domesticus*) where social interactions were tracked remotely and we used these interaction data to categorize animals in terms of sociability. Blood, hair, brain and other tissue samples from animals with extreme sociability phenotypes were collected. We then assessed the levels of three important cytokines (TNFα, IFNγ and IL1β) in the serum of these animals and tested whether cytokine levels could be explained by the sociability phenotype and/or sex of the mice. We found main effects of sex and sociability on the levels of TNFα, but not on IFNγ or IL1β. We discuss these findings in light of what is known about how each of these cytokines can impact behavior during illness. Our results indicate that, at baseline (or outside major disease events), certain elements of peripheral immunity may be associated with sociability. While it is known that several pro-inflammatory cytokines can impact behavior during illness, we are only now uncovering the possible effects that these immune mediators have on every day behaviors. Our findings help further our understanding of the multiple observed connections between immunity and social behavior.

P1-188 KING, T/P*; MARUSKA, K/P; Louisiana State Univ.; *tking21@lsu.edu*

Male social rank influences the immune response in an African cichlid fish

For species living in dominance hierarchies, social rank dictates access to resources and often contributes to reproductive success. To ensure survival, individuals constantly evaluate trade-offs between crucial biological systems, like the reproductive and immune systems, depending on their social rank and physiological state. Little is known about how social species balance interactions between immune system function and fluctuations in social status and reproductive fitness, particularly in fishes, the largest and most diverse group of vertebrates. Astatotilapia burtoni is ideally suited to address this question because males reversibly transition between dominant reproductively-active and subordinate reproductively-suppressed phenotypes depending on their social environment. Here, we tested the hypothesis that immune responses differ with male social rank and reproductive state. We injected males with phytohaemagglutinin (PHA), a lectin that stimulates localized inflammation, and quantified differences in the width of the caudal peduncle in response to injection. We demonstrate that subordinate males have a greater difference in the width of their caudal peduncles (pre- vs. post-injection) compared to dominant males, indicative of the recruitment of more leukocytes and a stronger immune response. Sectioned spleens also showed differences in the quantity of macrophage centers between PHA and vehicle-injected males. Using qPCR, we are also comparing expression levels of pro-inflammatory cytokines in spleen and kidney of immune-challenged dominant and subordinate males. Because little is known about how reproductive physiology influences immune responses in fishes, this research provides greater insight into how socially plastic animals balance these trade-offs, with important implications for other taxa that exist in dominance societies.

21-5 KINGSOLVER, JG*; MOORE, ME; AUGUSTINE, KE; HILL, CA; UNC-Chapel Hill; *jgking@bio.unc.edu*

Responses of insect larvae to heat waves: what doesn't kill you makes you weaker

Climate change is increasing the frequency of heat waves and other extreme weather events experienced by organisms. How do the number and developmental timing of heat waves affect survival, growth and development of insects? Do heat waves early in development alter performance later in development? We addressed these questions using experimental heat waves with larvae of the Tobacco Hornworm, *Manduca sexta*. The experiments used diurnally fluctuating temperature treatments differing in the number (0-3) and developmental timing (early, middle and/or late in larval development) of heat waves, in which a single heat wave involved three consecutive days with a daily maximum temperature of 42 °C. Multiple (but not single) heat waves significantly reduced survival to pupation and pupal mass; the best model for the data indicated that both the number and developmental timing of heat waves affected performance. In addition, heat waves earlier in development significantly reduced growth and development rates later in larval development. Our results show that repeated, sublethal heat waves can have continuing and cumulative negative consequences for insects.

58-1 KINGSTON, ACN*; HAVENS, LT; CRONIN, TW; SPEISER, DI; University of South Carolina, University of North Carolina Chapel Hill, University of Maryland Baltimore County; *acnahm@gmail.com*

The visual system of the snapping shrimp, Alpheus heterochaelis: morphology, physiology, and visually-influenced behavior

Snapping shrimp (Decapoda: Alpheidae) are a family of crustaceans that have evolved a unique snapping claw that produces cavitation. Snapping shrimp with the most powerful snapping claws have evolved a form of specialized armor, the orbital hood, that covers their head and eyes. The presence of the orbital hood, along with the intriguing behavioral ecology of some species, has led to the hypothesis that snapping shrimp are blind. Here, we explore this hypothesis by examining the morphology, physiology, and behavior associated with the visual system of the big claw snapping shrimp, *Alpheus heterochaelis*. We find that *A. heterochaelis*, a snapping shrimp with a powerful snapping claw, has an orbital hood that covers the eyes completely and transmits 90% of incident light. The well-developed reflecting superposition compound eyes of *A. heterochaelis* are physiologically functional when tested using electroretinography (ERG) and microspectrophotometry (MSP). ERG indicates that snapping shrimp have a maximum spectral sensitivity near 500nm and demonstrate a flicker fusion frequency of 25-34hz. MSP shows that the visual pigments of *A. heterochaelis* are maximally sensitive to light at 501nm. Optomotor assays suggest that snapping shrimp can perceive and behaviorally respond to spatial cues. These results indicate that snapping shrimp are capable of detecting and responding to visual signals despite the presence of their orbital hood. In the future, we will study the co-evolution of weaponry, armor, and visual systems across Family Alpheidae.

72-7 KIRCHER, BK*; COHN, MJ; University of Florida; *kircherb@ufl.edu*

Development of a Sexually Dimorphic Character in Anole Lizards

Species vary widely in their patterns and magnitudes 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 (C2) cartilage in the hyoid system. We investigated the developmental basis of the sexually dimorphic dewlap apparatus in anoles and find that morphogenesis of the C2 skeleton diverges in males and females at a surprisingly early stage of development. Our results suggest that dewlap dimorphism is rooted in sex-specific regulation of early skeletogenesis.

62-5 KIRSCHMAN, L J*; MILLIGAN-MYHRE, K C; University of Alaska Anchorage; *ljkirschman@alaska.edu*

The effects of the mircobiota and host genetic background in defense against pathogens

The vertebrate gut microbiota plays key defensive roles by stimulating host immunity and by direct interactions with pathogens. For examples, colonization of the gut by mutualistic microbes is essential for the normal maturation of the vertebrate immune system, particularly the immune response and some microbes competitively exclude pathogens or pathobionts via interference or exploitative competition. However, multiple genes are associated with immune function and microbiota community structure, which can complicate the study of this system. Detangling the complexities of this host-microbiota relationship is important to understanding how vertebrates defend against enteric pathogens. However, many laboratory models used to study host-microbiota interactions use inbred models that lack genetic diversity, which may constrain inference regarding intra- and interpopulation differences in immune responses and pathogen susceptibility. In order to account for the effect of genetic background, we use threespine stickleback (Gasterosteus aculeatus) as a model species, because multiple populations of freshwater stickleback have evolved in isolation from common, anadromous ancestors and thus exhibit the high degrees of genetic variation. We raised two populations of stickleback in both germ-free conditions and in the presence of naturally occurring microbes and exposed them to a pathogen (Vibrio anguillarum) in a full factorial design. We measured how these treatments affected survival, immune gene expression, morphological development, and behavior. Our studies will elucidate the role of the host genetic background in the ability of the microbiota to protect the host from pathogens.

29-1 KISKADDON, EP*; DORGAN, KM; BERKE, SK; Dauphin Island Sea Lab, Siena College; *ekiskaddon@disl.org*

Impacts of the Deepwater Horizon Oil Spill on Phylogenetic Diversity of Benthic Infauna in the Northern Gulf of Mexico

Understanding ecological responses to environmental change is a core focus of ecology. While community responses are often quantified using taxonomy alone, biodiversity is inherently multidimensional. Functional, and phylogenetic information may therefore enhance insights gained from traditional taxonomic metrics. Here, we assessed the responses of two shallow benthic communities to oil disturbance using three dimensions: taxonomic, phylogenetic, and functional diversity. We hypothesized that disturbance would reduce all three metrics, but that impacts on functional diversity would be greater if oil affected one group more than others, e.g., subsurface deposit feeders. In contrast, if phylogenetic clades vary in their response to oil, the impact on phylogenetic diversity might be greater. We sampled benthic communities at two sites that varied in oil exposure following the Deepwater Horizon spill in the Northern Gulf of Mexico over two years. Infaunal communities were quantified from Ruppia seagrass beds and unvegetated habitats in both Fall and Spring of each year. Our results indicate a clear reduction in abundance and biomass of infauna following a reoiling event, with particularly significant reductions in the subsurface deposit feeding functional group. Phylogenetic diversity differed between site and habitat type, however no signal of oil disturbance was found when assessing phylogenetic diversity between the two sites. Overall, our results suggest that functional role in benthic communities is an important factor in response to disturbance.

20-2 KISSANE, KC; Blinn College; *kelly.kissane@blinn.edu*
Increasing Student Engagement and Retention in Biology by Using Outdoor Projects
Student retention in the STEM fields currently have a 52% retention rate in 4 year degree programs and only 31% retention rate in 2 year degree programs according to the US Department of Education. One way to increase both student engagement and student retention in biology is extra curricular activities that provide students opportunities to interact with nature. This talk will discuss three partnerships I developed at Blinn College to provide nature projects for students and the student reactions to these projects.

P1-162 KITTREDGE, MJ*; HAWK, A; MENG, O; LAMPARTER, M; THUL, T; PASK, G; Bucknell University; *mjk041@bucknell.edu*
PiSpy: Affordable Video Rig for Monitoring Animal Behaviors
Observations of animal behavior can be critical for many ethological questions, such as sensory responses to stimuli, locomotor activity, and eating habits. An automated system to monitor animal behaviors is a valuable tool in the field of ethology, but the cost can be prohibitive for many researchers, particularly those from low income countries. We have developed an affordable, customizable, and easy-to-use video monitoring device prototype, the PiSpy. The PiSpy platform is based on a Raspberry Pi computer and 8 megapixel Pi Camera and is designed to be able to record and monitor behaviors at any time in both light and dark conditions. To run this fully automated recording system, we developed a graphical user interface (GUI) to control each aspect of recording, such as frequency, duration, lighting control, etc. As a versatile recording device, PiSpy is able to adapt to the type of species it is monitoring, with the lights, video capture and frequency all adjustable, allowing research questions from many fields to be answered through it. Additionally, PiSpy is affordable at under $100, with many of the parts being home-made or easily attainable. We have piloted PiSpy in a range of studies such as ant tracking, beehive entrance monitoring, rat feeding behavior and locomotor activity in ground squirrels. We hope that our open-source PiSpy video recording platform, with its simplicity, adaptability and affordability, will contribute to many research advances within the biological sciences and beyond.

P1-201 KLEPAC, CN*; BARSHIS, DJ; Old Dominion University; *cklep001@odu.edu*
Physiological Evidence of Local Adaptation in the Massive Corals Porites lobata and Goniastrea retiformis from Ofu Island, American Samoa
Corals native to variable thermal environments often resist bleaching temperatures and survive exposures that typically bleach conspecifics from cooler environments; providing promising evidence for the persistence of reefs under projected global climate change. This bleaching resistance is attributed to acclimatory or adaptive conditioning to frequent sub-lethal water temperatures. Acclimatization plays an important role in modifying thermal thresholds and has been observed within 1 week and up to 2 years in Acropora corals. However, it is not known how many species are capable of thermal acclimatization. From 2015-16, populations of two massive corals, *Porites lobata* and *Goniastrea retiformis*, were transplanted from three contrasting backreefs in Ofu Island, American Samoa, into a highly variable (HV) pool known to elicit increased bleaching tolerance. Following one week, six, and twelve months, transplanted and native coral samples were exposed to a controlled acute thermal stress assay. Physiological bleaching responses - chlorophyll concentration and photosynthetic efficiency - were quantified to characterize heat stress responses. For both species, corals transplanted into the HV pool had reduced photochemistry and pigment. Variation in thermal tolerance was instead driven by native backreef, not acclimatization or genomic differences. Moreover, comparisons of HV coral growth and bleaching response data suggest trade-offs in fitness versus stress tolerance. Summer temperatures of 2016 surpassed regional records, and HV pool variability increased in magnitude, potentially reaching local stress thresholds. This study strongly contrasts previous research conducted in the Ofu pools, indicating that distinct coral species use fundamentally different strategies to respond to and resist thermal stress.

P2-177 KLINE, GE*; TIBBS, LE; JUDSON, JM; JANZEN, FJ; Iowa State University, Iowa State University ; *grkline@iastate.edu*
The Role of CIRBP in Temperature-Dependent Sex Determination in Painted Turtles
The sex of many reptile offspring is determined by the temperature at which the eggs are incubated. Still, how thermal cues are transduced to molecular signals and then to gonadal differentiation is poorly understood in species with this temperature-dependent sex determination (TSD). Recently, researchers found that the Cold-inducible RNA-binding protein (CIRBP) encoding gene is expressed differently at male- and female-inducing temperatures in the common snapping turtle (*Chelydra serpentina*), which has TSD. We examined a key SNP of the CIRBP gene in painted turtle (*Chrysemys picta*) hatchlings to see if differences in genotypes corresponded to differences in gender, as in *C. serpentina*. In the first study, the turtles were derived from eggs collected from one population and then incubated at 28 °C, which on average should yield a 1:1 sex ratio in this species. We extracted DNA from liver and ran PCR using primers designed specifically for the SNP. Of the 116 samples extracted, 84 yielded a high-quality sequence for analysis. We detected no variation in the 501 bp SNP region, although we found variation at other sites along the gene. Despite the absence of within-population variation in this SNP, we further extracted DNA from *C. picta* from distant localities with divergent climates, and still found no notable geographic differences in this SNP. Our findings suggest that the same SNP of CIRBP does not play identical roles in TSD of *C. picta* and *C. serpentina*. Even so, the remainder of the 5437 bp CIRBP gene has yet to be sequenced and analyzed, therefore this gene may still be important in the molecular biology of TSD in *C. picta*.

75-1 KLOEPPER, LN*; BRIGHTON, CB; MCGOWAN, K; ZUSI, L; TAYLOR, GK; Saint Mary's College, Oxford University; *lkloepper@saintmarys.edu*

Predator-prey kinematics of a specialized population of Swainson's hawks, Buteo swainsoni and Brazilian free-tailed bats, Tadarida brasiliensis

Predators and prey often exhibit coupled dynamics, especially during pursuit and evasion. These interactions require the coordination of complex sensorimotor control on rapid timescales, with a high potential cost for prey. Many predators and prey have co-evolved over time, resulting in an evolutionary arms race that can influence morphology and behavior. In this study, we investigate the pursuit and evasion strategies, respectively, of Swainson's hawks *Buteo swainsoni* and Brazilian free-tailed bats *Tadarida brasiliensis*. Bats are not typical prey of Swainson's hawks, but a small population of these birds have specialized to prey upon the seasonal population of free-tailed bats outside of one cave in central New Mexico. We recorded, with stereo video, the pursuit and evasion of hawks and bats during flight, and reconstructed 3D trajectories of individuals. From the trajectories we quantified flight behavior of predators including path, speed, attack angle, and acceleration; for the prey we quantified escape success, escape trajectory, flight speed, acceleration, escape angle, and reaction distance. We found mixed strategies for pursuit among hawks, and no stereotypical evasion strategies among individual bats. Our results suggest that the behavior of these populations has not likely co-evolved. Further, these findings suggest the strong potential for generalized antipredator responses in other species exhibiting localized, specialized predator-prey relationships.

105-3 KNIGHT, K.C.*; LEE, D.V.; Univ. of Nevada, Las Vegas; *kit.knight@unlv.edu*

Comparative biomechanics of horizontal, fine-branch locomotion in lizards: Part 1.

Squamates compromise the most speciose tetrapod order and move about their environments in many different ways. Evolutionary questions regarding structure-function relationships to allow for fine-branch walking using grip in lizards remain largely unanswered. Fine-branch walking is defined as climbing above and along a relatively thin, horizontal branch. In this part of the study, biomechanical and morphological variables are measured and compared in two pairs of lizard species: each pair are within an infraorder (Iguania and Gekkota) and are composed of a fine-branch specialist and ground generalist with some climbing ability. To understand the biomechanics and make relevant evolutionary comparisons of lizard fine-branch locomotion, each lizard species (n = 4) have been filmed with four high-definition, high-speed cameras while crossing a horizontal, segmented, instrumented beam system (Skywalk) that is able to measure minuscule 3D forces and torques. Two major locomotor modes have been identified: upright walking and belly-dragging. The relatively longer-limbed upright walkers (Specialist Iguanian and Gecko) use grip and produce torques in the fore-aft axis for propulsion and braking and in the left-right axis for balance measured by isolating each limb from a Skywalk segment. The belly-draggers (Generalist Iguanian and Gecko) always touch their belly above the Skywalk beam during locomotion and use their limbs to slide the body along. Recording 3D forces and torques for a single limb in the belly-draggers is difficult, thus comparisons of whole body kinetics were made. Comparisons between and within these groups are helping to shed light on structure-function relationships and evolution of fine-branch walking in lizards and may help with future studies in understanding the origins of grip in tetrapods.

112-6 KNOX, C.E.S; CHAN, K.Y. K*; The Hong Kong University of Science and Technology, Swarthmore College; *kchan1@swarthmore.edu*

Size does matter: Respiratory response of twin urchin embryos to acidification

Increasing dissolution of carbon dioxide in the surface ocean, the process of ocean acidification, is expected to incur overall negative effects on various marine organisms. Often, these impacts are sublethal, e.g., reduction in growth, calcification, and elevated per unit size metabolic rates. These effects are well-documented for the vulnerable, yet crucial, life history stage of the planktonic larvae of the sea urchins. However, these responses, especially in terms of body growth, are not uniform within a single family, between parental lineages, between populations of the same species, and between species. Our earlier work also showed that some larval urchins S*trongylocentrotus purpuratus* and other echinoids release blastula-like particles when exposed to low pH. One hypothesis is that delay in growth and the process budding/tissue shredding reduce the overall size of the larva, and hence, the total metabolic demand. By applying blastomere separation techniques, we tested if embryos of *S. purpuratus* of reduced-size were less affected by acidification. Our observations suggested that the relatively smaller twins (~80% of the unmanipulated embryos) were relatively less impacted by ocean acidification: the increase in oxygen consumption was smaller between the embryos reared under control (pH 8.0) and acidified (pH 7.3) conditions. Our results reinforce the notion that some organismal response, e.g., reduced growth and budding, could provide short-term advantages for survival under stressful conditions. However, such phenotypically plastic responses observed likely come at long-term developmental cost.

3-4 KNUTIE, SA; University of Connecticut; *saknutie@gmail.com*

Effects of supplemental feeding on the gut microbiome and parasite resistance of Eastern Bluebirds

Supplemental feeding of birds by humans can affect host-parasite interactions. For example, increased food availability can have both a positive and negative effect on parasite resistance in the host. These interactions could be mediated by the host's gut microbiota because studies have found that host diet can affect their gut microbiota and gut microbiota can affect the immune system. In this study, I determined the effects of supplemental feeding on interactions between Eastern Bluebirds (*Sialia sialis*) and their parasitic nest flies (*Protocalliphora sialia*) in northern Minnesota. Specifically, I tested whether experimental manipulations of mealworm availability and parasite abundance affect gut microbiota and the antibody-mediated immune response in Bluebirds. I found that supplemental feeding of Bluebirds dramatically reduced parasite abundance compared to unsupplemented birds, which was mediated by the nestling antibody response. Gut bacterial diversity increased in supplemented nestlings and this diversity was negatively related to parasite abundance and positively related to the antibody response. These results suggest that supplemental feeding of bluebirds can improve the health of the birds by increasing their resistance to parasites, which could be mediated by the gut microbiota of nestlings.

P1-58 KO, DD*; LIN, H-T; Imperial College London; *dsk13@ic.ac.uk*

The Role of Head Roll during Dragonfly Visual Guidance

Dragonflies are impressive aerial hunters, accurately catching their prey in chases that last less than a second. Their success hinges on not only their excellent vision but also careful positioning of their eyes relative to their bodies and their targets to efficiently extract relevant information for guidance. This general visuomotor technique is a form of active vision. Dragonflies steer their eyes with the head precisely in both conspecific pursuits and prey interceptions. This active head rotation results in a specific projection of the prey image on the retina and therefore shapes the motion statistics the visual system perceives. This project aims to analyse this head motion as the dragonfly transition from cruising flight, to prey interception and then conspecific chases. Specifically, we focus on the head roll axis which ultimately sets the visual reference frame for processing motion information. We will introduce preliminary data and analysis on the head roll with respect to target positioning and velocity in in both free-flight and tethered experiments. Active vision holds multiple advantages over traditional fixed image acquisition techniques, as although visual data holds a great amount of information, this comes at the cost of expensive computation. By tactically shaping the visual input signal, the dragonfly can inspire efficient approach to autonomous visual guidance.

2-7 KOBIELA, ME*; SNELL-ROOD, EC; Univ. of Minnesota, Twin Cities; *kobie003@umn.edu*

Anthropogenic Increases in Sodium Alter Life History and Stress Tolerance in Monarch Butterflies

Sodium, a micronutrient essential for muscle and neural function in animals, has historically been limited in availability for many terrestrial herbivores. Humans have recently increased the amount of available sodium by using deicing salts on roads and through agricultural irrigation. Using butterfly larvae as model herbivores that are common along roads, previous research showed that moderate increases in sodium may slightly benefit butterflies by allowing them to develop larger brains or flight muscles, but large increases are toxic. Several questions remain: How much genetic variation exists for selection to act on altered life history traits in moderately salted conditions or survival under high salt? How does stress from additional sodium along roadsides interact with other stressors? To address these, we used ten maternal families of monarchs *Danaus plexippus* reared on low- and moderate-sodium milkweed (*Asclepias syriaca* - consistent with concentrations found along roadsides in Minnesota). We measured survival, development time, body size, fecundity, eye size as a proxy for neural investment, amount of protein in flight muscles, and recovery from cold stress as adults. We found moderate genetic variation for survival and other life history traits in response to salt. However, families differed greatly in their life history tradeoffs or correlations among traits - in other words, there was no one genotype that showed universally positive or negative effects of increased sodium. Interestingly, we found that males fed salted milkweed were more tolerant of freezing temperatures than those in the control group. This work not only informs monarch conservation, but also adds to our knowledge of how anthropogenic changes in nutrient availability affect life history evolution more broadly.

24-8 KOCH, JC*; VERDE, EA; WEIS, VW; Oregon State University (OSU), Maine Maritime Academy, OSU; *kochja@science.oregonstate.edu*

Low carbonic anhydrase activity in Elliptochloris-containing Anthopleura elegantissima and the negative correlation between diameter and carbonic anhydrase activity.

The sea anemone *Anthopleura elegantissima* is a prominent member of the intertidal zone on the west coast of North America and can exist in three symbiotic states: a white, brown, or green state where anemones lack symbionts, contain predominantly *Breviolum muscatinei*, or *Elliptochloris marina*, respectively. The enzyme carbonic anhydrase (CA) catalyzes the interconversion between CO_2 and HCO_3^{-1} and is known to play a dynamic role in delivering CO_2 to symbionts embedded deep within host gastroderm. To test the effect of symbiotic state and anemone size on CA activity *in hospite*, *A. elegantissima* were collected near Anacortes, WA, flash frozen in the field, and subsequently processed for CA. In addition to activity, corresponding gene expression of several CA isoforms was evaluated using RT-qPCR. Brown anemones displayed significantly higher CA activity than either greens or whites and greens unexpectedly displayed CA activity equal to that of whites. CA activity, when normalized to anemone protein, was highest in small anemones and lowest in large anemones (small > medium > large); furthermore, regression analysis showed a significant inverse correlation between anemone size and CA activity. *Breviolum* has much greater rates of primary productivity than does *Elliptochloris* so higher CA activity in brown anemones is expected in order to provide their algae with unrestricted amounts of CO_2 to satisfy photosynthetic carbon demand. The negative correlation between anemone size and CA activity is hypothesized to be driven primarily by the surface area to algal density relationship. We propose that small anemones have smaller photosynthetically active surface area yet have similar algal densities to large anemones, necessitating higher CA activity to provide adequate CO_2 for photosynthetic activity.

89-3 KOCH ADRIAN, R.E.*; DAMIAN, D.K.; Monash University; *rebecca.adrian@monash.edu*

Dropping like flies: Testing the role of mitochondrial genetic variation in negative geotaxis response

Sequence variation in the mitochondrial genome of animals has recently been discovered to have functional consequences on life-history traits like lifespan and fecundity. Moreover, evidence for "Mother's Curse" mutations have been found in some systems: mutations in the mitochondrial DNA (mtDNA) that have harmful effects on males, but not on females, due to the maternal inheritance of mitochondria. However, functional mtDNA variation and Mother's Curse mutations have been explored only in a limited number of traits, even in the model system of the fruit fly (*Drosophila melanogaster*). Mitochondrial function itself is known to affect a broad range of physiological traits, including neural function and motor performance, and it remains uncertain whether these traits may be affected by variation in mtDNA. In this study, we test a composite measure of behavior, neural function, and motor performance in fruit fly strains that each possess a unique and naturally occurring mtDNA haplotype in an otherwise strictly standardized nuclear genetic background. Using a novel apparatus, we tested each strain for negative geotaxis response (climbing height, a product of time spent orienting and walking) after a controlled drop on to a firm surface. We tested all flies from 5 to 20 days of age, as negative geotaxis in fruit flies is known to show age-related declines that are sensitive to oxidative stress—a key physiological variable in mitochondrial biology. We found differences in negative geotaxis response across age groups, between the sexes, and among strains, and the decline in response with age also varied across strains. Our results demonstrate that variation in mitochondrial DNA alone can have functional effects on a behavioral trait with neural and motor underpinnings.

100-7 KOEHL, MAR; Univ, of California, Berkeley;
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How Ambient Flow Affects the Locomotion of Small Organisms

When organisms locomote in nature, they must navigate through complex habitats that vary on many spatial scales, and they are buffeted by turbulent wind or water currents and waves that also vary on a range of spatial and temporal scales. We have been studying the effects of body shape and of swimming or crawling behavior by microscopic organisms on their motion through the environment as they are carried by turbulent ambient flow. Using both mathematical models and experiments with the microscopic larvae of bottom-dwelling marine animals, we found that local shear rotates small organisms, thereby changing their swimming direction. While spherical bodies keep spinning in shear, elongate bodies rotate until they line up with the shear. Swimmers travel differently in turbulent flow than do non-swimmers, and are more likely to encounter nearby surfaces but less likely to remain there than non-swimmers. Thus, microscopic organisms can bias the way that they are transported by ambient flow. Body shape and orientation also affect the drag on small organisms crawling on surfaces, so shape coupled with the adhesive strength of crawlers constrains the flow microhabitats in which they can operate.

33-1 KOELLER, K.L.M.*; STOCKER, M.R.; University of Florida, Virginia Tech; *kkoeller3115@gmail.com*

Investigating the Patterns of Convergence in Pectoral Girdle Reduction During the Evolution of Limblessness in Lerista (Scincidae)

Over 30 tetrapod lineages have evolutionarily lost their limbs. Studies of limb and digit loss have revealed a close relationship between the reduction of the appendages and body elongation; however, the reduction and loss of internal structures like the pectoral girdle have been less thoroughly examined. Here, we use computed tomography to examine pectoral girdle morphologies in the skink genus *Lerista*, which contains pentadactyl and limbless members, as well as transitional morphologies. Our 3D geometric morphometric analysis demonstrates that the loss of the pectoral girdle occurs gradually and in a series of steps loosely associated with the extent of forelimb reduction. The girdle as a whole shows more pronounced reduction anteroposteriorly than mediolaterally, occuring in fairly close association with limb reduction. Certain events occur concurrently such as the loss of the coracoid foramen, which occurs in association with the loss of the humerus. However other events, such as the loss of the epicoracoid, are not consistently associated with any state of limb reduction. Patterns of reduction are clade dependent, with individuals from closely related groups showing dramatically different degrees of girdle reduction despite a similarity in limb state. Despite these differences, the patterns of girdle reduction in *Lerista* are more similar to each other than to those of other skinks, and are more similar to other skinks than to other squamate groups. Though some aspects of this transition are common to all squamate lineages that have evolved limblessness, this study reveals that even in closely related clades within the same genus, the evolution of limblessness does not proceed in an entirely deterministic way.

48-2 KOHN, GM*; APODACA, J; MUñOZ, M; STREBE, S; WHITE, SA; WRIGHT, TW; Dept of Biology New Mexico State University, Dept of Integrative Biology and Physiology, UCLA, New Mexico State University; *gmkohn@nmsu.edu*

FoxP2 expression and vocal learning abilities in the budgerigar (Melopsittacus undulatus)

Vocal learning is a rare trait found in only a few lineages of mammals, including humans and three taxa of birds: parrots, songbirds and hummingbirds. Birds and humans share many analogous neurogenetic mechanisms underlying this key cognitive trait. In particular, the transcriptional factor FoxP2 appears to play a conserved role in vocal learning across most vocal learning clades. Budgerigars are notable for exhibiting life-long vocal learning abilities, which they use to develop shared contact call repertoires with mates and social associates. They also show chronic down-regulation of FoxP2 in MMSt a brain region essential for vocal learning. We hypothesized that such down-regulation is critical to maintaining open-ended learning abilities in budgerigars. We used AAV viral vectors and targeted stereotaxic injections to overexpress FoxP2 in the MMSt of male budgerigars and compared their vocal learning abilities before and after the FoxP2 manipulations. Males were placed with a novel female three weeks before injections and recorded daily to establish baseline learning rates. They then received injections of either the FoxP2 AAV or a control GFP, allowed to recover for two weeks, and then placed with a new novel female and recorded for an additional three weeks. Preliminary results based on 5 males in each treatment suggest that FoxP2 overexpression disrupts the ability of budgerigars to learn contact calls from females, supporting the hypothesis that chronic down-regulation FoxP2 is an essential component of their lifelong vocal learning abilities

32-3 KOLMANN, MA*; COHEN, KE; BEMIS, K; SUMMERS, AP; IRISH, F; HERNANDEZ, LP; George Washington University, University of Washington, Virginia Institute of Marine Science, Moravian College; *mkolmann@gmail.com*

The Whole Tooth and Nothing But: Tooth Replacement in Piranhas and Pacus

Carnivorous piranhas and herbivorous pacus have curious dentitions for teleosts; many species show some degree of heterodonty attributed to adaptations for either carnivorous or herbivorous diets, respectively. Tooth replacement in piranhas is also unusual - all the teeth on one side of the head are lost as a unit, then replaced simultaneously. Moreover, the arrangement and shape of teeth in serrasalmids is a principal means of distinguishing between many genera. We used CT scanning and histology to examine tooth replacement across serrasalmids, and map replacement characters onto a molecular phylogeny. Pacu teeth develop and are replaced in a manner similar to piranhas. All serrasalmids (with one notable exception) share a unilateral tooth replacement pattern, so this is not an adaptation for carnivory. However, this unilateral replacement mode is not an ‘all or nothing' phenomenon - we present evidence that both sides of the jaws have developing tooth rows within them, albeit one is more mineralized than the other. These patterns are found to be consistent over ontogeny in size series of the piranha *Pygocentrus* and the pacu *Metynnis*. Additionally, both pacus and piranhas use accessory tooth cusps to interlock adjacent teeth together, forming dental batteries. We propose that this interlocking mechanism (and perhaps heterodonty) begets simultaneous replacement and ensures that functionality of the feeding apparatus is not interrupted by tooth loss, as might occur in other instances of polyphyodont tooth replacement. Finally, we propose that this mode of simultaneous replacement be considered as a synapomorphy for the family.

P2-219 KOLMANN, MA*; IRISH, F; HERNANDEZ, LP; George Washington University, Moravian College; *mkolmann@gmail.com*
Muscled Up and Sutured Down: Cranial Musculature & Feeding Mechanics in Piranhas and Pacus
The serrasalmid fishes, pacus and piranhas, exhibit considerable dietary diversity, feeding on fins, scales, and whole fishes to the seeds, fruits, and leaves of aquatic and terrestrial plants. These prey span both an ecological and a biomaterials continuum, from tough plant fibers and silicated matrices to the chitin, muscle, bone, and sinew of animal prey. Serrasalmids feed on such prey using jaws with only a few degrees of freedom; essentially the jaws are constrained to only dorso-ventral abduction/adduction. Compared to other bony fishes, serrasalmids have fused most of their cranial skeleton together, resulting in an akinetic skull with with little obvious proclivity for jaw protrusion. How can such a 'simple' skeletal arrangement result in such dietary diversity? We describe the gross anatomy of the feeding morphology and infer functional themes across the serrasalmid fishes using both manual dissection and contrast-enhanced µCT scanning. We document hidden myological complexity in serrasalmids, stemming in particular from the divergence in lever mechanics between herbivorous pacus and carnivorous piranhas. Piranhas in particular seem constrained in cranial space, jaw adductors appear to have displaced branchial musculature posteriorly. Pacus and piranhas feature different arrangements, fiber architecture, and hypertrophy of select adductor mandibulae divisions, we suspect as a means of augmenting jaw leverage for different occlusal regimes. These occlusal modes presumably relate to gape limitation incurred by different prey: granivorous and frugivorous pacus feed on large, ovoid prey items while piranhas are frequently gouging chunks of flesh, fins, or scales from prey.

P3-79 KOLONIN, AM; CALVILLO, PA*; ASPBURY, AS; GABOR, CR; Texas State University; *a_k282@txstate.edu*
Land Use Conversion Affects Stress and Life-History of Stream Fish
Human-induced habitat alteration from land use conversion is one of the main drivers of decreased biodiversity and health in freshwater ecosystems. Urbanized environments produce run-off that introduces pollutants and alters water temperature, chemistry, and hydrology which can affect the physiological stress response of resident fishes by elevating or dysregulating their primary stress hormone, cortisol. The stress response is an important and energetically costly hormone-mediated mechanism that allows organisms to adjust their behavioral, physiological, and life-history phenotypes in response to environmental disturbances. However, prolonged stress can become maladaptive and lead to long term suppression of growth, reproduction, and immune function, thereby directly influencing population declines. Some species of fish are able to persist despite environmental challenges and stressors while other are not. We explored the consequences of land use conversion on baseline cortisol release rates, stress response (to agitation), and life history plasticity of the common mosquitofish, *Gambusia affinis*, which persist in urbanized habitats while other fish perish. We sampled two urban and two rural streams (defined by % impervious cover) within geographical proximity. We found that *G. affinis*, in urban populations, has significantly elevated baseline and agitation cortisol levels compared to rural populations. Further, urban populations of *G. affinis* had higher reproductive allotment (RA: dry brood mass). There was also a significant positive relationship between RA and cortisol. Our findings suggest that *G. affinis* behave as opportunistic adaptors and are able to modulate their reproductive output in lower quality streams.

P1-280 KOLUCH, MP*; BURTON, K; OHRENBERGER, J; FARINA, S; GIDMARK, NJ; Knox College, Univ. of New Hampshire, Howard University; *mpkoluch@knox.edu*
Biomechanical and histological explorations of bendable tooth attachments in goosefish
Teeth are diverse in their morphology and function among fishes to accommodate a variety of feeding and prey capture strategies. Fully formed teeth typically require rigid attachments to the jaws, but attachments for developing teeth must be mobile to accommodate growth. Therefore teeth are typically non-functional while developing and only become functional once they become fixed ("ankylosed") to the jaw. Goosefish (*Lophius americanus*) have some ankylosed teeth along the labial rim of the jaw but also have a large proportion of half-developed teeth, which are attached only on the lingual side by a ligament. This provides a hinging mechanism that allows the teeth to bend freely to allow prey into the mouth, while the ligament locks the teeth in place labially to prevent prey from leaving the mouth. We used a lever motor and high-speed video to test resistance to bending of both tooth types (ankylosed and hinged) in both lingual and labial directions. The hinged teeth bend more than 90 degrees in the lingual direction with little force (less than 1 Newton), whereas almost no bending (less than 10 degrees) is seen with high forces (above 8 Newtons) in the labial direction. Ankylosed teeth bent little in either direction. We also examined this ligament histologically via paraffin embedding and generalilzed contrast stain. This ligament is composed entirely of collagen (with no elastin), suggesting that the ligament is inelastic. This study demonstrates functional utility during multiple phases of tooth development in goosefish.

139-4 KORNEV , K.*; ZHANG, C.; SANDE, L.; POMETTO, S; BEARD, C; ADLER, P; Clemson University Presenting Author*, Clemson University; *kkornev@clemson.edu*
Self-Assembly and Repair of the Butterfly Proboscis: the Role of Capillary Forces
The proboscis of butterflies and moths consists of a pair of C-type fibers, called galeae, which are developed separately in the pupa and when the butterfly emerges from it, these two galeae are still separated. We observed that proboscis self-assembly is facilitated by discharge of saliva. In contrast with vertebrate saliva, butterfly saliva is not slimy and is an almost inviscid, water-like fluid. Butterfly saliva, therefore, cannot offer any viscoelastic adhesiveness. We hypothesize that the saliva meniscus is used by butterflies to bring and hold the galeae together while locking them in place. Theoretical analysis supported by X-ray micro-computed tomography on columnar liquid bridges suggests that both concave and convex liquid bridges are able to pull the galeae together[1, 2]. The image analysis of meniscus profiles confirms the model predictions. Experiments on sedated butterflies when the muscular action was diminished but saliva was present, show the crucial role of saliva meniscus in brining galeae together. Experiments on live butterflies and theory confirm that the adult insects are able to self-repair proboscises after separation of galeae. References 1. Zhang, C.Q., et al., Self-assembly of the butterfly proboscis: the role of capillary forces. Journal of the Royal Society Interface, 2018. 15(144): p. 20180229. 2. Why spit is key to building a butterfly. Nature, 2018. 560(7716): p. 2.

P3-96 KOROTASZ, AM*; BRYAN, AL; Savannah River Ecology Lab; *korotasz@mail.usf.edu*
Accumulation of ^{137}Cs by Carnivorous Aquatic Macrophytes (Utricularia spp.) on the Savannah River Site
Plants are an important mode of transfer of contaminants from sediments into food webs. In aquatic ecosystems, contaminant uptake by macrophytes can vary by path of nutrient uptake (roots vs. absorption from water column). Carnivorous plants likely have additional exposure through consumption of small aquatic organisms. This study expanded on previous research suggesting that bladderworts (Genus *Utricularia*) accumulate radiocesium (^{137}Cs) and examined for (1) a potential association between sediment and plant concentrations and (2) differences in ^{137}Cs accumulation among rooted and free floating *Utricularia* species. A strong correlation was found between average ^{137}Cs concentrations in all *Utricularia* species (combined) and sediments (r_s = 0.9, p = 0.0374). Among three bladderwort species at common sites, *Utricularia floridana*, the only rooted species, had higher mean ^{137}Cs concentrations than *Utricularia purpurea*, and *U. purpurea* had a greater mean ^{137}Cs concentration than *Utricularia inflata*.

P3-77 KOTNOUR, JL*; GLOVER, M; MBUYU, N; MCPEEK, S; WRIGHT, NA; Kenyon College; *kotnourj@kenyon.edu*
Interactions of life history traits and locomotion investment across the avian tree
Across the avian tree, species drastically differ in their locomotion style, particularly the extent to which they invest in flight vs. terrestrial locomotion. Bird species are equally as varied in their life histories. We investigated how this investment impacts a species' life history across five life history traits: rate of development, nest type, flight style, body size, and main method of obtaining food. The diagonal length of the sternal keel and length of the tarsometatarsus were used to quantify the investment in forelimb and hindlimb locomotion, respectively. We measured the long bones and keels of over 2,000 individuals from museum collections, representing the majority of avian families and all major branches of the avian tree. We employed phylogenetic generalized linear models to explore the coevolutionary relationship between flight investment and life history traits. We found the relative investment of forelimbs to hindlimbs was predicted by life history. A species' investment in their locomotion was well predicted with their primary mode of obtaining food; species that obtained food primarily through ground and arboreal foraging tended to have lower flight investment.

P2-186 KRAJNIAK, K.G.*; TEPEN, Z; SWANSON, N; Southern Illinois University Edwardsville; *kkrajni@siue.edu*
The response of the Isolated Earthworm Crop-Gizzard to the Annelid Oxytocin Related Peptide, Lumbricus1
Oxytocin and related peptides are present in animals from most phyla including Annelida. In the earthworm *Eisenia fetida* annetocin excites the isolated crop-gizzard. Our lab showed that this peptide and other oxytocin related peptides also stimulated the crop-gizzard of *Lumbricus terrestris*. Two oxytocin related peptides are predicted in the genes of the earthworm of *Lumbricus rubellus*, Lumbricus 1 and 2. Therefore, we tested Lumbricus 1 on the crop-gizzard of the related species *L. terrestris*. 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. Lumbricus 1 may cause an increase in contraction rate and a biphasic response in contraction amplitude. Of the nine trials, five showed an increase in rate with Lumbricus 1, however the variability of the data led to large standard error bars when graphing the average response. The contraction amplitude data exhibited too much variability between each trial to determine any effect. Throughout each of the trials, a biphasic response was observed, but no persistent nature was seen between them. Since oxytocin was excitatory on all preparations tested in the past, we are currently challenging the same crop-gizzard preparations with alternating, increasing doses of oxytocin and Lumbricus 1. This regimen should clarify the effects of Lumbricus 1 on the isolated earthworm crop-gizzard.

11-5 KRENTZEL, D*; ANGIELCZYK, K; Univ of Chicago, Field Museum; *dkrentzel@uchicago.edu*
Constraints or Functional Innovations? An Integrative and Comparative Approach to Understanding the Astounding Diversity of Rodent Feeding
Discerning the role of constraints and functional conservatism in the presence of static character evolution is a central problem in evolutionary morphology. Differentiating these scenarios is impossible without a synthesis of evolutionary history with anatomical, functional, and ecological data. Here, we use a clade level approach to structure-function relationships, comparative biomechanics, and detailed myology of extreme test cases to reveal the complex functional capabilities of an otherwise seemingly constrained set of evolving characters in rodents. The simplicity of rodent gnawing dentition allows for an enormous range of dietary/functional specializations without qualitative structural anatomical changes, and independent evolutions of superficially similar masseter arrangements do not correlate with similar functions. Further, the only major changes to the mostly static Eocene-age masseter arrangements in recent rodent evolution are found to occur independently in the most derived ricochetal rodents that lose much of their temporalis musculature, but not in myomorphic ricochetal rodents with preexisting complex anterior masseter arrangements. This latter result independently validates our comparative biomechanic findings that the myomorphic masseter arrangement replaces temporalis functions generally, creating a unique mammalian masticatory system. These data demonstrate that complex existing functional capabilities can underlie morphological stasis and that stasis need not indicate morphological constraint or functional conservatism.

4-5 KRIEFALL, NG*; MATZ, MV; KANKE, M; DAVIES, SW; Boston University, University of Texas at Austin, Cornell University; *nicfall@bu.edu*

Host and Symbiont Genetic Structure in the Coral Acropora hyacinthus Across Two Divergent Reef Zones

Recent advances in population genomics have facilitated the discovery of adaptive divergence of marine organisms across contrasting environmental conditions at unexpectedly small geographic scales despite their high potential for gene flow. *Acropora hyacinthus*, a broadcast spawning reef-building coral, is highly dispersive and can populate environmentally distinct reef zones: the backreef (i.e. greater diel variability in temperature, light, and other factors) and forereef (i.e. proximate to open ocean; more stable environmental conditions). Adaptive genomic divergence across habitats could allow these corals to thrive in both environments. Alternatively, these divergent environments could select for different communities of algal symbionts (Symbiodiniaceae) that influence host performance. Here, we sampled *A. hyacinthus* colonies at paired backreef-forereef sites off the French Polynesian islands of Moorea (two paired sites) and Tahiti (one paired site). We performed 2b-RAD genome-wide de novo genotyping to examine host genetic divergence and metabarcoding of the ITS-2 locus to characterize symbiont community composition. Our results suggest that while subtle genetic structure exists between islands (Tahiti vs. Moorea), no significant population structure in coral hosts between reef zones was observed. However, our analyses of potential loci under selection in the host genome between reef zones are ongoing. Lastly, algal symbiont community compositions across all sites and reef zones were homogenous. Although our ongoing genomic analyses will provide further insight, our current results suggest that acclimatization may play a more significant role than host genetic structure and algal symbiont communities in coping with divergent reef zones in this dispersive coral species.

29-2 KRINOS, AI*; DIXON, K; ROSS, A; STOCK, CA; Geophysical Fluid Dynamics Lab, OAR, NOAA; *akrinos@vt.edu*

Understanding spatial effects of climate change on Chesapeake Bay blue crab using statistical downscaling and agent-based modeling

Blue crab are an important economic resource in Chesapeake Bay, worth $78 million in 2009 (Chesapeake Bay Foundation). Blue crab are also an important link in the Bay ecosystem and a symbol of the Bay, particularly to local residents and fishermen. Climate change may impact the complex migration and reproduction strategies of blue crab, in particular their distribution and abundance. In this study, we develop a spatially-resolved, agent-based mechanistic blue crab population model. Using this approach, we can approximate observed fluctuations in the population on a monthly timestep, and simulate genetic variation and responses to environmental stimuli on short timescales. The effects of climate change on living resources is difficult to determine reliably via coarse global climate models. Statistical downscaling is increasingly used to apply model output to regional scales relevant to local biological processes. Here, we apply the Quantile Delta Mapping (QDM) bias correction method (Cannon et al. 2015) to Max Planck Institute Earth System Model (MPI-ESM) climate projections at low resolution. We use resulting historical and projected temperature and precipitation estimates as inputs to a Bay water balance model (Muhling et al. 2017). This model predicts surface temperature and salinity, estuarine habitat indicators which we use to drive our blue crab population model. We hope to use this model to show the possible trajectory of blue crab stock under the MPI-ESM-LR climate change scenario. Refining these estimates through updated models is key to informing the management of blue crab in the Chesapeake Bay.

P2-196 KRINOS, AI*; MEDINA, DM; HUGHEY, MC; WALKE, JB; GAJEWSKI, Z; SARMENT, LS; BELDEN, LK; Virginia Tech, Virginia Tech / Vassar College, Virginia Tech / Eastern Washington University, Virginia Tech / University of Michigan; *akrinos@vt.edu*

An evaluation of the predictive potential of gene sequences for antifungal capacity of amphibian skin bacterial isolates

Recently, amphibian skin bacteria have been isolated and sequenced as part of an initiative to develop probiotic-based approaches to mitigate infection by the pathogenic fungus Batrachochytrium dendrobatidis (Bd) in wild amphibians. Bioinformatics is increasingly used to infer the inhibitory ability of bacteria based on short-read amplicon data (~250 bp of the 16S rRNA gene) by matching these sequences to a database of Bd-inhibitory isolates. However, anti-fungal predictions made solely via sequence-based similarity are rarely validated. Here, we matched sequences of the bacterial 16S rRNA gene of 22 isolates from the skin of two endangered Atelopus frog species to sequences in the database, and used the database to predict the anti-Bd ability of each isolate. We then performed in vitro challenge assays to determine whether the isolates behaved as predicted. We found that the database only predicted the outcome of the challenge assays for 55% of the isolates, suggesting a fair amount of uncertainty in using sequence matching to assign anti-Bd properties of amphibian skin bacteria without actual challenge assay data.

112-2 KRISHNAMURTHY, D*; BENOIT DU REY, F; LI, H; CAMBOURNAC, P; KORKMAZHAN, E; PRAKASH, M; Stanford University, ISAE-SUPAERO; *deepak90@stanford.edu*

Anti-gravity Machine: Multi-scale Imaging and Measurement of Plankton Behavior using a Novel Tracking Microscope

Marine microscale plankton are the fundamental drivers of ecological processes in the ocean. These organisms serve as biological engines powering the ocean's geochemical cycles including carbon sequestration and vertical material transport. Understanding plankton behavior and ecology is therefore essential for understanding our planet's health and climate. A key aspect of marine ecology is the Diel Vertical Migration (DVM) of plankton, whereby individual plankton migrate over vertical scales orders-of-magnitude greater than their individual size. This is one of the largest migrations of bio-mass on our planet, occurring daily. This vast separation of scales makes mechanistic and quantitative study of plankton physiology (sub-cellular scale) and macroscale behavior (scales of meters), a challenging problem. We present a novel and simple solution to the above mentioned problem using a "Hydrodynamic treadmill", in conjunction with tracking microscopy to result in a system that allows unrestricted vertical motion of objects while allowing sub-cellular scale imaging at high time resolution. We demonstrate this method by conducting a comparative study of freely swimming marine invertebrate larvae such as *P. miniata* (Bat Star), *P. parvimensis* (Sea Cucumber), *O. spiculata* (Brittle star)and *S. purpuratus* (Sea Urchin); and marine diatoms, dinoflagellates and marine snow. Our method allows us, for the first time, to measure microscale physiology and micro-behavioral states in marine plankton and directly measure their connections to macroscale behavior. The capabilities of this method may be extended to study sub-cellular scale processes such as calcium signaling and relate them directly to organismal behavior, thus leading to mechanistic insights into plankton behavior.

P2-64 KROHMER, RW; ALCALA, DM*; Saint Xavier University; *krohmer@sxu.edu*

Colocalization of Aromatase and Nitric Oxide Immunoreactive Neurons in the Forebrain of the Male Red-Sided Garter Snake

Nitric oxide (NO) first identified as an endogenous regulator of blood vessel tone, may also serve as a neurotransmitter. With a half-life of less than five seconds, NO has been examined by assessing the presence of enzymes responsible for the formation of NO. The NO producing enzyme, reduced nicotinamide dinucleotide phosphate-diaphorase (NADPH-d) is broadly distributed in the mammalian and avian brain, particularly in steroid-sensitive areas implicated in the control of reproductive behavior. In addition, distribution of NADPH-d corresponds to areas with dense populations of cells containing the aromatase enzyme (ARO). Previously, we found aromatase immunoreactive (ARO-ir) cells to occur at all levels of the male red-sided garter snake (RSGS) brain. However, cells containing the highest concentration of ARO-ir were concentrated in regions classically associated with the control of courtship behavior and mating. In the current study, we examined the anatomical relationship between ARO and NO by labelling ARO-ir and NADPH-d (NO-ir) cells. The distribution of ARO-ir cells was similar to that reported by Krohmer et al (2002) with NO-ir cells significantly overlapping the ARO-ir cells in regions critical for the control of courtship behavior, such as the preoptic area, bed nucleus of the stria terminalis, nucleus sphericus, hypothalamus, and septum. Tissues double labelled for ARO and NADPH-d revealed a possible co-localization of these enzymes within the same cell subset. Based on these data, the close association of ARO-ir and NO-ir cells suggest input from NO-positive neurons may modulate the expression or activity of ARO in the male red-sided garter snake brain.

9-2 KRUPPERT, S*; TAYLOR, J; Friday Harbor Laboratories, University of Washington, Scripps institution of oceanography; *sebastian.kruppert@googlemail.com*

Shells in a changing ocean: the impact of ocean acidification on mollusk vulnerability

Marine mollusks depend on their heavily calcified shells as body armor against a range of predators, including the formidable smashing mantis shrimp. While it has been established for multiple species of mollusks that ocean acidification-like conditions reduce calcification, it is not known how this change in mineralization manifests in the mechanical integrity of their body armor in the context of predation attempts. We hypothesized that changes in calcification in response to medium-term exposure to reduced pH conditions will be sufficient to alter the material properties of the shell in ways that reduce its impact resistance. We tested this hypothesis on two California mollusk species, the mussel *Mytilus edulis* and the periwinkle *Littorina planaxis*, that are common prey of the mantis shrimp *Hemisquilla californienses*. A total of 64 small individuals of each species (*Mytilus*: 47.4±3.1mm, *Littorina*: 9.2±0.7mm) were exposed to ambient (pH = 8.2) and reduced pH (stable 7.9, 7.6, fluctuating: 7.9±0.05) conditions for 10 weeks, after which shell growth was documented and shell hardness and stiffness were determined using nanoindentation. The experimental conditions were sufficient to induce significantly lower growth rates in the reduced pH treatments compared to the ambient control group. Mineralization is yet to be analyzed, but our nanoindentation measurements suggest that there is no effect of pH on shell hardness and stiffness in *M. edulis* and *L. planaxis*. Thus, for small molluscs, exposure to ocean acidification conditions may not cause changes sufficient to alter the function of their calcified armor.

P3-4 KUKAJ, A.*; ESCALANTE, G.; ELLERS, O.; DICKINSON, P.; JOHNSON, A. S.; Bowdoin College; *akukaj@bowdoin.edu*

Force-velocity relationships in cardiac muscles of the American lobster, Homarus americanus

Crustacean hearts provide a comparatively simple model for understanding the mechanics of heart function. As with all hearts, the work done by the lobster heart creates pressure that circulates blood, or hemolymph, throughout the body. The ability of the heart to do work depends on heartbeat frequency and amplitude. When tissues need more energy, the heart can increase the volume being pumped into and out of the heart by increasing these variables. Such functional changes can alter the stretch imposed on the heart by elastic pulls and pressure changes during contraction and relaxation, which, in effect, alter the length of the intrinsic muscles of the heart. Similarly, increases in frequency will alter the velocity at which the heart changes length. We assessed the characteristic length-tension and force-velocity relationships of the lobster heart and quantified how these relationships change with increased inotropy as induced by SGRNFLRFamide (SGRN), an endogenous neuropeptide in *H. americanus*. We found that (1) the lobster heart length-tension curves fit the general pattern observed for cardiac length-tension curves from other species in that the active force generated by the muscle increases up to a point with increasing muscle length, (2) the lobster heart force-velocity curve resembles the iconic curve in that contractility of the heart increases as lengthening velocity increases and decreases as shortening velocity increases, (3) SGRN shifts the length-tension curve up, thereby increasing heart contractility, and (4) SGRN decreases the effect of velocity on force during both lengthening and shortening of the heart. These relationships among tension, length and velocity and neuromodulators such as SGRN enable flexibility in the heart's response to cardiac demand.

P2-57 KUNSELMAN, LF*; SANCHEZ, N; KINGSTON, AC; SPEISER, DI; Univ. of South Carolina; *lfk@email.sc.edu*

Characterizing the Optic Lobes of the Florida Fighting Conch Strombus alatus

Conch (Gastropoda: Strombidae) possess strikingly large and complex eyes for a gastropod mollusc. The presence of relatively complex eyes suggests that the neural structures associated with visual processing in conch may also be more complex than those observed in other gastropods, which tend to have relatively small eyes or no eyes at all. In this study, the optic lobes of the Florida fighting conch *Strombus alatus* were characterized using ethyl gallate as a neurohistological stain. Brains were harvested and fixed overnight in 2% glutaraldehyde, 1% paraformaldehyde, and 0.16 M cacodylate buffer. Following fixation, the brains were immersed in osmium tetroxide for several hours and transferred to a saturated ethyl gallate solution for two more hours. The conch brains were then sectioned, and photographs of the sections were used to create 3-D reconstructions of the brains. The optic lobes of *S. alatus* appear to be larger and more complex than those of other gastropods. In the future, the tracing of optic nerves with fluorescent lipophilic dyes will be utilized to more fully describe how the photoreceptors in the eyes project to the optic lobes of *S. alatus*.

P2-26 KVISTAD, L*; AMOS, N; AUSTIN, L; FALK, S; GAN, HM; LOW, G; MORALES, H; PAVLOVA, A; STIER, A; WALTERS, J; SUNNUCKS, P; Monash University, Deakin University, University of Gothenburg, University of Glasgow; *lynna.kvistad@monash.edu*

Neo-Sex Chromosomes May Drive Mitonuclear Selection in the Eastern Yellow Robin

Mitonuclear interactions may be drivers of climate adaptation and lineage divergence. The Eastern Yellow Robin (EYR) shows 6.8% mitogenome sequence divergence between inland and coastal populations. This variation correlates with climatic factors, suggesting possible metabolic local adaptation. Differentiation of the nuclear genomes of populations that bear different mitolineages is heterogeneous for markers mapped to a Zebra Finch (ZF) reference genome; it is particularly strong for a 15.4 MB region mapping to ZF autosome 1A that contains an overrepresentation of nuclear genes (32) with mitochondrial functions. In the hybrid zone of the two mitolineage-bearing EYR populations, differentiation in this 15.4 MB region is strong between females and virtually absent in males. To investigate this, 10x whole genome resequencing data for 100 birds were mapped to a draft EYR genome. The 32 mitonuclear genes from the 15.4 MB region were then mapped to two kinds of EYR scaffold: one limited to females, and one seen in both sexes but with half the read-depth in females than males. This supports the hypothesis that 15.4 MB region may be inherited as a neo-W chromosome with corresponding neo-Z. Neo-sex chromosomes may be overlooked by assuming synteny to a reference. The inferred neo-sex chromosome architecture presents a candidate explanation for the female-limited selection previously indicated in EYR. These ideas are being tested by comparative genomics, measurements of mitochondrial and whole-bird respiration, and fitness estimates.

P1-268 LABATCH, NR*; POWELL, CL; LANDBERG, T; Arcadia University ; *nlabatch@arcadia.edu*

Effects of ontogeny and sexual dimorphism on jump performance in the Cave Cricket (Ceuthophilus spp.)

Sexual dimorphism often results in different relationships between morphology and performance for males and females. Increased loads associated with reproductive investment often hinder female locomotor behavior. However, sexual selection could help compensate for increased loads and reduced escape performance by increasing the length and mechanical advantage of limbs. We tested this hypothesis in Cave (aka Camel) Crickets (*Ceuthophilus* spp.) and predicted that cave cricket females would have longer legs than males for a given body size in order to allow for increased load during reproductive cycles without decreased escape performance. We simulated predator attacks and measured average jump distance in 120 individuals. As predicted, females were heavier for a given total length when compared to males and juveniles (ANCOVA; p=0.0339) and have longer legs for a given total length than males and juveniles (ANCOVA; P=0.0048). Females, males, and juveniles all jumped similar distances for their leg length (ANCOVA; p=0.7877). Our results suggest that sexual selection on jump performance in cave crickets has increased female leg length to compensate for reproductive load. This provides support for the differential equilibrium hypothesis which posits that sexually dimorphic life history strategies are caused by unique environmental pressures in male and female Orthoptera. Since female orthopterans are often larger than males, leg length may be under selection in other species with similar morphological constraints on morphology and escape performance.

P1-255 LAFOND, JC*; SAVAGE, AE; University of Central Florida; *lafondj@knights.ucf.edu*

Why won't Bullfrogs Die? A Study of Host Tolerance to Deadly, Fungal Pathogen

The fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*) has caused population declines and extinctions in hundreds of amphibian species globally. The American bullfrog (*Rana catesbeiana*) has been implicated as a vector species responsible for the global spread of *Bd*, however little is known about the genetic mechanism behind pathogen tolerance in this species. Many amphibian species experience natural selection acting on the Major Histocompatibility Complex (MHC) class II gene, a vertebrate immune gene that binds to foreign antigen proteins, facilitating T-cell recognition, and subsequent acquired immune response. Here we compared populations of *R. catesbeiana* with other well-studied populations to determine if MHC class II polymorphism could be responsible for the widespread tolerance to *Bd* expressed by *R. catesbeiana*. We collected genetic samples from three populations of the American bullfrog from across its North American range. We also collected samples of the lowland leopard frog (*Rana yavapaiensis*), a species with intermediate *Bd* susceptibility that varies among populations. *R. yavapaiensis* samples were taken from two populations; one population that had developed tolerance to *Bd* via MHC class II, and another that had not. We amplified, and sequenced MHC class II genes from all populations, and quantified the number of beneficial alleles shared between species. The proportion of MHC class II beneficial alleles was determined in each *R. catesbeiana* population and was compared against the proportions found in the tolerant and non-tolerant populations of *R. yavapaiensis*. Determining if phenotypically divergent species evolve the same way in response to disease remains an important question for amphibian conservation. Our study aims to broaden our understanding of the immunogenetic evolution of species that appear to be ubiquitously tolerant to *Bd*.

P1-262 LAGGAN , N.A.*; JOYCE, L.; MCMAHON, T.A.; The University of Tampa, University of Montana; *Nicholelaggan@gmail.com*

Exploring the infection dynamics of Batrachochytrium dendrobatidis and soil nematodes: A host parasite system

Batrachochytrium dendrobatidis (Bd) has caused the mass decline of hundreds of species globally; posing a serious threat to biodiversity, ecosystem health and stability. Most of the research on this topic has focused on Bd and amphibian interactions because of the severe devastation in frog populations, but Bd has been found in other non-amphibian hosts (e.g. crayfish and soil nematodes) as well. Understanding the host-parasite interaction between Bd and its non-amphibian hosts is essential for understanding the dynamics in the wild, developing applicable epidemiological models, and functional management plans. In this experiment, we examined the interaction between soil nematodes (*Caenorhabditis elegans*) and Bd. We exposed soil nematodes to Bd on agar dishes with no other food resources and maintained these organisms for up to several weeks, photographing each adult nematode daily to document the infection dynamic. Nematodes were exposed to Bd and E. coli in an agar plate and the proportion of nematodes that moved to each food resource was documented. Bd exposure did not alter adult nematode length throughout the infection ($\chi^2_1 = 0.43$, $p = 0.51$), but did increase vulva bulging ($\chi^2_1 = 5.18$, $p = 0.02$). Bd zoosporangia emerged from the nematode body through the vulva and Bd infection reduced nematode movement over time ($\chi^2_1 = 8.95$, $p = 0.003$). We also saw nematodes moved towards Bd as a food resource. These results indicate that Bd impacts both nematode survival and mobility. Bd may impact nematode survival in the wild, but further research is required to understand the full extent of these infection dynamics.

33-2 LAILVAUX, SP*; MISHRA, A; HOQUE, MT; WILSON, RS; University of New Orleans, University of Queensland; *slailvaux@gmail.com*

A machine learning approach to predicting the multivariate performance phenotype

Morphology -> performance relationships are well understood for individual performance traits, particularly in species that are highly specialized for conducting specific ecological tasks. However, the environment places multiple and often conflicting demands on organismal morphology and physiology. A proper understanding of the multivariate morphology -> performance relationship is currently lacking, at least in part because of logistical challenges in measuring multiple performance capacities on the same individuals. We developed and trained a set of machine learning models and compared their predictive performances based on cross-validation using existing morphology and performance for over 30 lizard species. We then combined some of the best performing models, in a stacking manner, and formed the final robust model to produce novel predictions of unmeasured performance traits in those same species. We consider the accuracy, validation, constraints, and shortcomings of the model, as well as several potential applications of this approach

P1-244 LAMON, K. D.*; WILLIAMS, G. C.; Louisiana State University, Baton Rouge, California Academy of Sciences, San Francisco; *klamon3@lsu.edu*

Molecular Phylogenetics of Pacific Basin Octocorals — from Deep-Sea California to Pacific Coral Reefs

Corals are vital to many marine environments that depend on their diversity to sustain other marine organisms. Of the coral classes, Octocorallia is the most diverse, housing over half of all coral species diversity, but little is known of their phylogenetic relationships. Our objective for this study was to build a phylogeny for Pacific Basin octocoral families to understand their evolutionary relations. We sampled octocorals found in the deep-sea California waters and Pacific coral reefs as these regions contain a high abundance of octocoral species. We first surveyed the morphological diversity of sclerites, the skeletal scale-like components of corals, through scanning electron microscopy (SEM). We then used Sanger methods to sequence the ND6, ND2, and msh1 genes of 16 octocorals from a range of different families. Sequences were then aligned and concatenated within Mesquite and then used to build Bayesian and maximum likelihood trees. The topography and bootstrap values of these trees strongly suggest the order Pennatulacea and family Ellisellidae, which is placed in the suborder Calcaxonia, are sister taxa. We conclude that the designation of Pennatulacea as a separate order does not reflect evolutionary history and that the pennatulacean axis was likely derived from a calcaxonian ancestor. Future directions would include the addition of more samples from Ellisellidae and Pennatulacea to determine whether the support for our hypothesis remains strong. Our analysis would also benefit from a thorough comparison of the morphology of Pennatulacea and Ellisellidae. On a broader scale, sampling more species from other octocoral groups (scleraxonians, alcyoniinans, and holaxonians) could result in findings of other paraphyletic taxa within Octocorallia.

P2-156 LAMPTEY, DI*; COLOMBO, RE; MENZE, MA; MARTINEZ, E; EASTERN ILLINOIS UNIVERSITY, UNIVERSITY OF LOUISVILLE; *emartinez9@eiu.edu*

In the Heat of the Moment: Physiological Tradeoffs of Fishes Living in Warming Waters.

Currently, long-term responses of ectotherms to the warming trends observed in tropical regions are unknown, and they are significantly understudied due primarily to the difficulties in specimen and community traceability. In freshwater lakes employed as cooling reservoirs for power plants, increased physiological stress from high water temperature can lead to an increase in mortality, reduce growth and potentially alter the community structure of fishes. Throughout this study, we employed these lakes as highly tractable systems to assess how elevated thermal regimes can alter the physiology and consequently the ecology of the bluegill sunfish *Lepomis macrochirus*. Previous work documented a significantly reduced lifespan, growth performance, and a shift in the age structure towards younger individuals of *L. macrochirus* population inhabiting a thermally-impacted lake in Illinois, compared to a nearby non-impacted control lake of similar size. Results from our 30-day cross acclimation study showed that *L. macrochirus* were able to regain homeostasis within 4 weeks, as no significant differences in respiration rates were measured in fishes acclimated to 17.5ºC and 30ºC. It is hypothesized that thermally-impacted lakes has profound influence in mitochondrial function, where high temperatures could reduce energy transduction efficiency and potentially increase oxidative stress. This study raises questions about the causal relationships between physiological performance and habitat temperature, in particular how thresholds in an organism's physiology may modulate their community structure, and consequently their ecological success.

83-1 LANDBERG, T*; DEPACE, E; ABERNATHY, K; LUGINBUHL, C; MARSHALL, G; ROMANO, T; TUTTLE, A; TRIPP, J; TRIPP, S; Arcadia University, National Geographic Society, Luginbuhl Foundation, National Geographic Society, Mystic Aquarium, Tributary Mill Conservancy; *tobias.landberg@gmail.com*

Underwater Snapping Turtle Behavior Affects Dive and Surfacing Durations

Underwater activity increases the metabolic requirements of aquatic animals therefore air-breathing vertebrates adjust diving and surfacing durations to match their respiratory needs. Under lab conditions, CO2 build-up triggers turtles to breathe at the surface but they can hold their breath for hours during deep dives or months during winter. Unfortunately, studying free-ranging underwater behavior of shy freshwater turtles has been nearly impossible in densely-vegetated wetlands. To address this, we quantified the behavioral time budgets of adult snapping turtles (*Chelydra serpentina*) in Connecticut using an animal-borne video recorder (CRITTERCAM) with automatic detachment (n=12 turtles; 56h of video; 880 dives). Individuals displayed tremendous variation (range 5.3 to 60.8 surfacing events/hour) and on average spent 20% (±19% s.d.) of their time surfacing. Turtles at rest underwater remained submerged for long durations and at the surface continued resting in long bouts. As metabolically expected, active underwater behaviors like walking and swimming had shorter dive durations than resting behavior. Surprisingly, underwater activity limited surfacing duration as turtles re-submerged relatively quickly after feeding and locomotor behaviors (after accounting for the positive effect of previous dive duration). This remote imaging perspective shows how underwater behavior influences diving and surfacing patterns in wild snapping turtles and how remote imaging helps understand vagile yet cryptic creatures.

141-4 LANE, Z/M*; ZARDUS, J/D; MCELROY, E/J; KENDRICK, M/R; MORTON, S/L; College of Charleston, Charleston, SC, The Citadel, Charleston, SC, SCDNR, NOAA; *zachary.lane@usm.edu*

Working Smart not Hard: Loss of Active Feeding Behavior in the Commensal Sea Turtle Barnacle, Chelonibia testudinaria

Barnacles are sessile suspension feeders whose feeding efficiency and behavior is largely determined by the movement of water through their environment. In low flow environments, where particle capture is difficult, barnacles expend energy to feed actively, while in higher flow environments barnacles may feed passively which is more energetically efficient than active feeding. Many intertidal barnacles have been shown to switch between active and passive feeding modes as water velocities increase, but little is known about epibiotic species which are exposed to variable feeding currents and possibly display different behavior than intertidal species. To better understand the behavior of epibiotic barnacles, the sea turtle commensal *Chelonibia testudinaria* was raised to adulthood in the laboratory. Lab-reared adults (shell diameter = 12.63 ± 0.08 mm) were then subjected to a wide range of water velocities and their behaviors categorized and quantified with BORIS event logging software. Over the course of observation *C. testudinaria* displayed only passive feeding behavior, and at lower velocities, instead of switching to active feeding, did not feed at all. This species was most active between 20.63 and 53.59 cm s^{-1} as identified by logistic regression, a velocity range which correlates well with the average swimming speed of two common host species, loggerhead and green sea turtles, on which *C. testudinaria* resides. Lack of active feeding in this species may have evolved in concert with its epibiotic habitus, potentially making this species an obligate commensal, reliant on its hosts' movement to provide flow for particle capture as adults.

P1-109 LANE, S.J.*; LINKOUS, C.R.; BREWER, V.; SEWALL, K.B. ; Virginia Polytechnic Institute and State University, New Mexico State University ; *samjl89@vt.edu*

Female Aggression in Song Sparrows is Higher in Urban Habitats

Urban adapters are animals that are able to live in human-impacted areas, such as suburbs and cities. It has been hypothesized that urban adapters have behavioral phenotypes that permit them to persist in these human-impacted environments. Indeed, song sparrows (*Melospiza melodia*) live and breed in both urban and rural habitats and previous research has shown that urban males of this species show greater territorial aggression. However, little attention has been given to female behavior across urban and rural habitats. To determine if living in human-impacted habitats is associated with elevated aggression in female song sparrows, we simulated the intrusion of a conspecific female onto the social territory of focal females at two rural and two urban study sites in Blacksburg, VA. Specifically, we placed a model bird within 5 to 10 m of the focal bird's nest and played one of 6 exemplars of previously recorded female vocalizations. For 3 minutes without the model and 6 minutes after the model was exposed, we measured the focal female's distance from the speaker and the number of chitters, chets, growls, and buzzes produced by the female as a measure of aggression. We found that female song sparrows nesting in urban habitats were more likely to respond to a simulated female intruder and showed a greater behavioral response to conspecific intrusions than did females in rural habitats. This pattern of greater female aggression in urban habitats parallels previous reports of greater territorial aggression in males and raises the hypothesis that resource competition may be higher in urban environments, driving increased territorial aggression in both sexes of song sparrows.

79-2 LANG, A*; SANTOS, L; BONACCI, A; DEVEY, S; PARSONS, J; MOTTA, P; HABEGGER, M; Univ. of Alabama, Univ. of South Florida, Florida Southern College; *alang@eng.ua.edu*

Experimental Evidence of Flow Separation Control Leading to Decreased Drag by Shark Scale Bristling

The largest contributing factor of drag during swimming is generally that due to flow separation. It is hypothesized that the flexible denticles found on key body locations of the fast-swimming shortfin mako (*Isurus oxyrinchus*) shark aid in controlling flow separation. Previous work has documented that flank scales, located downstream of the gills, are capable of being actuated to angles of 40 degrees or more. Skin samples were affixed to a flat plate and placed in a water tunnel. A boundary layer was generated over a long plate, passed over the skin sample, and a region of flow separation was induced by the presence of a rotating cylinder located above the test area. The flow was measured by time-averaging thousands of velocity fields acquired using Digital Particle Image Velocimetry (DPIV). Flow separation was quantified using backflow coefficient, or the percentage of time the flow was reversed. Results show control of flow separation under both laminar and tripped turbulent boundary layer conditions. It should be noted that testing took place at speeds on the order of 0.5 m/s while burst swimming speeds can exceed 10 m/s. However, in spite of this lack in flow similarity separation control was demonstrated. This shows the main mechanism is Re independent, in that controlling the flow involves the scales reaching into the bottom 5% of the boundary layer to inhibit flow reversal occurring near the wall that leads to global flow separation and pressure drag. Large scale 3D printed models of shark denticles have also been fabricated (from a characteristic length of 0.2 mm on real skin to 1 cm for the models) to match flow similarity to the lower testing speeds. Scale actuation and flow control have also been observed using the 3D printed scale models.

62-6 LANGFORD, ML*; CAIN, S; HOWARD, JA; FRANKS, BR; Florida Southern College, Jacksonville University; *mlangford@flsouthern.edu*

I'll have a side salad with that: Bonnethead sharks, Sphyrna tiburo, host cellulose-degrading bacteria within their digestive tracts

The bonnethead shark, *Sphyrna tiburo*, is a commonly found elasmobranch species along the Florida coast. Bonnethead sharks frequently ingest seagrasses in addition to a diet of crustaceans, molluscs, and cephalopods. Cellulose degrading enzymes within the hindgut have previously been detected, and a recent metabolic study has demonstrated that *S. tiburo* is capable of digesting seagrass; however, the role of microbes in the digestion of plant matter remains unclear. Here, we sought to determine whether bonnethead sharks within the Tampa Bay Estuary contain bacteria capable of digesting plant material within their digestive tracts. The stomach, anterior intestine, proximal spiral, mid spiral, distal spiral intestines, and colon from two adult sharks were each screened for the presence of cellulose degrading bacteria. Positive bacterial isolates were individually tested for cellulose degradation, and subsequently identified by 16S rRNA gene sequencing. We report the first isolation and identification of bacteria from within *S. tiburo* stomach and intestinal tissues that exhibit cellulase activity, a marker of plant degradation. These findings suggest a possible mechanism whereby *S. tiburo* may be able to obtain nutrition from plant matter.

51-6 LANGKILDE, T*; ADAMS, T; AVERY, J; WARNE, R; Penn State, Southern Illinois; *tll30@psu.edu*

Effects of anthropogenic noise on wood frog tadpoles

Anthropogenic noise is pervasive across habitats throughout the world. Noise from human activity can adversely affect animal behavior, especially for animals that rely on sound to communicate, as well as potentially induce physiological stress. Hydraulic natural gas fracturing and its associated transportation is a novel source of anthropogenic noise across large areas of the North Eastern United States. Despite the wide distribution and potential impacts of this emerging noise for wildlife, few studies have tested for hydraulic fracturing noise effects, especially in aquatic habitats. Here we examine whether noise originating from natural gas compressor stations affects larval wood frog (*Rana sylvatica [Lithobates sylvaticus]*) survival, development, behavior, and stress physiology. Our results indicate that elevated noise levels and associated vibrations, in conjunction with exposure to an additional chasing/handling stressor, can have lethal consequences for tadpoles during early developmental stages. At later developmental stages, however, noise without direct vibration did not affect tadpole survival, morphology, behavior, or stress physiology. As such, amphibian fitness may be effected by increasing global levels of anthropogenic noise, but such effects may be context or stage-dependent.

P2-19 LANZA, AR*; SEAVER, EC; University of Florida, 1989; *alexislanza@gmail.com*

Insights into the role of TGF-β superfamily signaling in annelid dorsal-ventral axis formation

TGF-β superfamily signaling regulates a variety of developmental processes and has a conserved role in patterning the dorsal-ventral body axis. Within this signaling family, there are two distinct branches: the Activin/Nodal pathway and the BMP pathway. Recent studies in some spiralian species have suggested that BMPs play a crucial role in dorsal-ventral axis patterning. Here, we investigate patterning of the dorsal-ventral axis in annelids. Previous pharmacological inhibition studies in the annelid *Capitella teleta* suggests that signaling via the ALK4/5/7 receptor patterns the dorsal-ventral axis, implicating the Activin/Nodal pathway. In this study, we further determine the mechanism of the Activin/Nodal pathway as it functions in *C. teleta* axis patterning, as well as the role of TGF-β superfamily signaling in the more basally branching annelid, *Chaetopterus variopedatus*. In *C. teleta* embryos we utilize antisense Morpholino Oligos that target SMAD2/3, a pathway specific component, and then score larvae for phenotypic analyses. Secondly, early cleavage stage embryos of *Chaetopterus* were exposed to various chemical inhibitors, raised to larval stages, and scored for axial anomalies. Similarities between *Chaetopterus* and *C. teleta* are revealed as chemical interference with the Activin/Nodal pathway but not the BMP pathway results in larvae that lack detectable dorsal-ventral axes. Furthermore, our results suggest TGF-β superfamily signaling functions differently in annelids than in their spiralian counterparts, the mollusks. Comparative analysis using *C. teleta* and *Chaetopterus* sheds light on the mechanism of TGF-β signaling and the ancestral state of annelid dorsal ventral axis patterning, thus contributing to our understanding of how changes in developmental programs lead to evolution of spiralian body plans.

11-6 LAPSANSKY, AB*; TOBALSKE, BW; University of Montana; *anthony.lapsansky@umontana.edu*

The Comparative Biomechanics of Aerial and Aquatic Flight in Alcids

Roughly 40 species of birds across five extant clades have co-opted their wings for use in underwater propulsion, here termed "aquatic flight", while retaining their aerial flight. This group serves as an ideal case-study in evolution under distinct selective pressures, as water is 800X denser and 60X more viscous than air. Consider that the major component of force produced by a bird in aerial flight is oriented to counteract gravity. In contrast, buoyancy is the dominant force in aquatic flight at most depths. Thus, this dual-media strategy requires that the same bird produce forces in opposite directions with the same morphological structures. How aquatic flight is accomplished, and the potential tradeoffs of this strategy, are unclear. We recorded the kinematics of five species of alcids in water and air at the Alaska SeaLife Center and off the California coast. For underwater flights, we coupled this with qualitative analysis of the wake visualized using bubbles released from the plumage. In all species, we found that the aquatic downstroke produced lift that contributed to horizontal thrust and 'weight-support', as it does in aerial flight. The aquatic upstroke produces a strong downward-oriented force, counteracting buoyancy and the upward momentum of the downstroke. Thus, the upstroke has a unique function in aquatic flight. The upstroke generates circulation and ventrally-directed lift in select sequences and drag-based force in others. Further negative lift was apparent in underwater gliding sequences during which birds accelerated ventrally without wing movement. We also observed substantial feather deformation during underwater flight. We hypothesize that this is facilitated by a swept-wing posture, and that this deformation directs force production to increase hydrodynamic efficiency.

P2-200 LAROCHE, R. A.*; BENEDICT, C.; TITUS, B. M.; RODRIGUEZ, E.; MEYER, C.; University of Houston, Auburn University, American Museum of Natural History, American Museum of Natural History, National Museum of Natural History; *rasl850148@gmail.com*

First Characterization of the Clownfish-Hosting Sea Anemones Microbiome Across Host and Habitat

The relationship between clownfish and sea anemones is, arguably, the most recognizable example of symbiosis on the planet. The relationship stems from the ability of the clownfish symbionts to live with immunity among the otherwise lethal tentacles of sea anemones. It is broadly understood that this immunity stems from the interplay between the mucus coating covering the clownfish and the mucus coating produced by the sea anemone. These mucus layers, containing important microbial communities and metabolic compounds, serve as the interface of the entire symbiosis. Although the taxonomic and functional diversity of the microbiome within these layers may shed light on the emergence and health of this symbiosis, it remains entirely uncharacterized. Here we use high-throughput 16s amplicon sequencing to characterize the microbiome of host anemones *Entacmaea quadricolor, Heteractis magnifica, Stichodactyla mertensii, Heteractis aurora*, and *Cryptodnedrum adhaesivum* from the Maldives. We further explore the taxonomic and functional diversity of the *H. magnifica* microbiome from anemones sampled on atoll fore reef communities that host clownfish symbionts and those from shallow (1m depth) reef channel anemones that do not host fish. This study provides the first glimpse into the taxonomic and functional diversity of the microbiome of the clownfish sea anemones.

136-7 LAROUCHE, O*; FRIEDMAN, ST; WAINWRIGHT, PC; PRICE, SA; Clemson University, South Carolina, University of California, Davis; *olarouc@g.clemson.edu*

Do marine and freshwater fishes differ in rates and directions of body shape evolution?

Ray-finned fishes have repeatedly colonized both marine and freshwater habitats. Several clades have experienced increased diversification rates following marine to freshwater transitions, yet it remains to be seen if these transitions also consistently lead to higher rates and changes in the direction of morphological evolution. To investigate this hypothesis, we measured eight ecologically and functionally relevant size and shape variables, combining length, depth and width measurements, on 5000+ museum specimens from 2735 teleostean species. We explored a binary and a more complex habitat categorization scheme and analyzed the evolutionary history of habitat use through stochastic character mapping. The fit of single and multi-rate Brownian models of trait evolution was then compared to identify possible rate differences among habitat categories. We found that although marine and freshwater taxa largely overlap in their morphospace occupation, size is an important component of the total variation and delimits a cluster of predominantly freshwater species of smaller body sizes. However, when size is removed, marine species occupy a considerably larger region of morphospace compared to freshwater taxa. The greatest rate differentials among habitat categories were obtained for depth and width variables, which evolved at the fastest rates in marine fishes. Our results highlight differences in body depth/width ratio as an important component of the disparity patterns in marine species, which may have functional consequences as these traits are linked to maneuverability. One possible explanation is that marine habitats have a greater range in structural complexity, leading to a wider array of optimal forms.

P2-192 LARSON, A M*; KANATOUS, S B; Colorado State University, Fort Collins; *spashley@rams.colostate.edu*

Temporal Examination of Myoglobin and Myosin Heavy Chain Expression Patterns in Skeletal Muscle Cells

Myoglobin is a hemoprotein that is involved in oxygen storage and transport, a nitric oxide and reactive oxygen species scavenger, and has shown interactions suggesting a role in cellular lipid transport. Typically, myoglobin expression follows an established slow muscle fiber type. These slow muscle fibers contain a protein called myosin heavy chain I and are found in endurance muscles. Interestingly, recent evidence has shown a change in myoglobin expression without a change in fiber type. This indicates that myoglobin expression is not always fiber type dependent and could be expressed through alternate mechanisms. Our lab has shown that mixed lipid supplements elevate myoglobin levels in cells from terrestrial and marine mammals, but it is unknown how these supplements affect myoglobin expression relative to the fiber type of the cultured tissue. To investigate, we have cultured and differentiated C2C12 myoblasts in the presence and absence of lipid. Cells were then harvested each day after differentiation initiation. Western blots were conducted to ascertain the expression of myoglobin and myosin heavy chain I and assayed for functional myoglobin content. With these methods, we have found myoglobin expression prior to that of myosin heavy chain I. This could indicate that there are pathways to myoglobin expression independent from fiber type expression. Examination of alternate routes of myoglobin expression that are not reliant on fiber type establishment could yield potential therapeutic benefits to combat ischemic diseases seen in humans.

P2-283 LARTER, M*; DUNBAR-WALLIS, A; BERARDI, A E; SMITH, S D; University of Colorado, Boulder, University of Bern, Switzerland; *maximilien.larter@gmail.com*

Evolution of floral pigmentation and regulation of the anthocyanin pathway in Iochrominae

Anthocyanins are the main class of pigments found in flowers, and are largely responsible for determining floral hue and color intensity. Even over relatively short evolutionary timescales, radical changes in flower pigmentation have occurred in many plant genera. However, the genetic mechanisms underlying these changes at the species level are generally unknown. It is thought that because of pleiotropic effects, the core genes of the pathway are unlikely to suffer deleterious mutations, preserving the vital roles of the pathway products in other tissues. This suggests an important role for regulatory changes in the evolution of floral pigmentation. We use HPLC to identify and quantify floral products of the anthocyanin pathway, and qPCR to measure gene expression of 7 core genes of the pathway, in 28 species (3 individuals per species) of the Iochrominae clade (Solanaceae). We found that complete losses of floral anthocyanins are convergently due to down-expression of three late genes of the pathway. We are currently using transcriptomics to identify the regulatory elements responsible for these changes in a subset of species. Additionally, we aim to further our understanding of the control of metabolic flux through the pathway, i.e. which genes are reducing or increasing the total amount of pathway products, and the ratio of products, for example anthocyanins vs. flavonols.

6-1 LASALA, JA*; HUGHES, C; WYNEKEN, J; Florida Atlantic University; *jlasala1@fau.edu*

Breeding sex ratios in a mainland population of Leatherback sea turtles

Species that display temperature dependent sex determination are at risk for decline due to increasing global temperatures. High temperatures can decrease hatching rates and cause hatchlings to be increasingly female, which may skew adult sex ratios. The relationship of hatchlings sex ratios to adult sex ratios remains complicated. Adult sex ratios are difficult to assess because marine turtles are widely distributed, individuals may or may not breed annually, and males remain at sea. A functional alternative measure is sought: breeding sex ratio (BSR). One method to quantify BSR is to identify the number of males that successfully contribute to each nest by examining paternity of hatchlings. We sampled nesting Leatherback (*Dermochelys coriacea*) mothers and their hatchlings from two mainland beaches in southeastern Florida and conducted exclusion analyses to identify breeding males. Sampling occurred over multiple nesting seasons (2014-2017) and included over 180 nests and over 2500 hatchlings. We found that female Leatherbacks nesting in both locations were from the same population and that the breeding sex ratios are 1.9M : 1F. These US mainland nesting Leatherback turtles may be more promiscuous than at other Atlantic island nesting sites (57% of all nests analyzed had multiple paternal contributions). We found over 225 individual males that contributed individually to nests, but only one example of a male mating with more than one female, suggesting this population is highly polyandrous. Baseline breeding sex ratios are important because they establish how mating affects the population structure of these turtles before effects of extreme environmental impacts drive changes in demographics and behavior.

16-1 LASKOWSKI, KL*; DORAN, C; BIERBACH, D; WOLF, M; Leibniz Institute of Freshwater Ecology & Inland Fisheries; *kate.laskowski@gmail.com*

Tracking the Developmental Trajectories of Behavioral Individuality in a Clonal Fish

Individual behavioral variation is ubiquitous across the animal kingdom. Classic quantitative genetics predicts that such phenotypic variation should arise as a result of variation in genetics and the environment. Recent work however challenges this classic paradigm: considerable individual behavioral variation develops even among genetically identical clonal fish raised under identical conditions. This suggests that the traditional theory explaining the presence of individual phenotypic variation is limited by only focusing on what generates this variation but not how. Using the clonal fish, the Amazon molly (*Poecilia formosa*), we explored how early life experiences, in particular social experiences can generate feedback mechanisms that ultimately drive the emergence of behavioral individuality even among otherwise identical animals. Using an innovative high-resolution tracking system we followed the behavior of isolated individuals and small sib groups all day, every day, from birth for the first four months of their lives. These data offer unprecedented insight into the trajectories of individual behavioral development allowing us to pinpoint when and how individuals change their behavior in response to social cues.

51-1 LASLO, M*; HANKEN, J; Museum of Comparative Zoology, Harvard University; *mlaslo@g.harvard.edu*

Thyroid hormone signaling-related gene expression in the hind limbs of the direct-developing frog Eleutherodactylus coqui

Direct development is a novel reproductive mode that has evolved independently in at least ten anuran lineages. Direct-developing frogs, including the Puerto Rican coquí, *Eleutherodactylus coqui*, hatch from terrestrial eggs as miniature adults. While their embryonic development resembles metamorphosis in several respects, many traits develop in a different sequence compared to those in metamorphosing frogs. For example, limb development follows thyroid gland formation and occurs well after hatching in metamorphosing frogs. In contrast, limbs in direct-developing frogs begin to form early in embryogenesis and well before the thyroid, suggesting that their development is thyroid hormone (TH) independent. TH concentrations increase in the *E. coqui* embryo after thyroid gland formation, although maternal THs are present in the newly fertilized zygote. Thyroid hormone receptor (TR) and deiodinase expression dynamics and the increasing TH titer suggest that the last third of *E. coqui* limb development is TH-dependent. To determine if all TH-signaling genes share similar temporal expression patterns between these two contrasting life histories, we sequenced the hind-limb transcriptome of *E. coqui* and *Xenopus tropicalis* at three equivalent stages. While two TH-signaling genes, *TRβ* and *dio2*, share similar expression patterns in both species, a third gene, *TRα*, does not. Expression of *TRα* increases over time in *X. tropicalis*, whereas it decreases after thyroid gland formation in *E. coqui*. Our data are consistent with TH-mediated embryonic limb development in *E. coqui*, but the initial source of TH may be maternal rather than embryonic.

P2-16 LASLO, M; JUST, J*; ANGELINI, DR; Harvard University, Colby College; *jjust@colby.edu*

Beyond D. melanogaster: Insect Sex Determination in the Large Milkweed Bug

The determination of a sex phenotype is a fundamental process in the development of sexually dimorphic organisms. Despite the ubiquity of sexually dimorphic animals, sex determination pathways vary greatly among them, indicating their subjectivity to evolution. However, little is known about their molecular and genetic details in most organisms other than mammals and *Drosophila melanogaster*. Hence, the heteropteran *Oncopeltus fasciatus* provides a novel model organism to the study of sex determination in insects. *O. fasciatus* has three orthologs of *doublesex (dsx)*, the master regulator of sex determination in *D. melanogaster*, as well as single copies of other genes acting in fruit fly sex determination, such as *intersex (ix)*. In *D. melanogaster* and many other insects, *dsx* regulates sexually dimorphic development via alternative splicing. RNAi of single orthologs in *O. fasciatus* do not alter sex determination, indicating potentially redundant functions of the orthologs. RNAi knockdowns of *ix* produce intersex phenotypes, demonstrating the factor's crucial role in wildtype sex. We are conducting triple- and double-knockdowns of the *dsx* orthologs to further investigate the role of *dsx* in the sex determination of *O. fasciatus* as well as the potential redundant function of the three orthologs. Additionally, we are interested in the role that alternative splicing of *dsx* and *ix* plays in the sex determination of *O. fasciatus* and are conducting qRT-PCR analyses to investigate the presence of sex-, age-, and tissue-specific splicing isoforms. Our results will provide new detailed insights into the sex determination pathway of an under-studied but species-rich group of organisms.

P3-137 LATTANZIO, M; Christopher Newport Univ.; *matthew.lattanzio@cnu.edu*

Parallel Patterns of Climate-Mediated Spatial and Temporal Morph Turnover in a Color Polymorphic Species

The evolution and maintenance of color polymorphisms inferred to represent alternative mating tactics are most often studied within the framework of sexual selection theory. Indeed, morphs typically diverge in key factors tied to reproductive success such as social dominance, mate access, and territory quality. However, this emphasis limits our appreciation of the range of other parameters capable of influencing the evolution of color polymorphic systems. For example, in some lizards, heterogeneous morph spatial dispersion patterns occur that suggest a link between morph occupancy and local climatic regimes occurs as well. I capitalized on a long-term dataset on male ornate tree lizards (*Urosaurus ornatus*) to test the hypothesis that color morphs linked to alternative mating tactics also diverge in environmental tolerances. Males were scored visually as expressing one or two of the three putative color alleles (o, b, y), and climate data were obtained for each locality-year combination. My findings reveal allele-specific patterns of climate-mediated turnover over a seven-year period that are remarkably congruent with allele occupancy patterns across 56 localities spread through a broad portion of the species' geographic range. Specifically, blue alleles were most strongly associated with wetter and cooler years/habitats, and orange alleles were more likely to occur in hotter and drier years/habitats. In contrast, yellow alleles exhibited no clear climate associations in either dataset. Collectively, these findings support that the underlying physiological differences among competing morphs influence their relative survival across an environmental gradient as well as their mating success. In a broader sense, the joint effects of these processes could serve to enhance a polymorphic species' capacity to persist in lieu of environmental change.

79-3 LAUDER, GV*; WAINWRIGHT, DK; SAADAT, M; DOMEL , AG; DOMEL, G; WEAVER, JC; ANKHELYI, MV; POPP, M; WEN, L; BERTOLDI, K; Harvard Univ., Notre Dame Univ., Beihang Univ.; *glauder@oeb.harvard.edu*
Shark Skin: Three-Dimensional Structure and Hydrodynamic Function
The skin of sharks consists of numerous tooth-like scales (denticles) that form a rough surface covering the body. Imaging this surface has mostly been accomplished using (two dimensional) scanning electron microscopy. But in order to understand the hydrodynamic function of shark skin, it is critical to quantify surface roughness in three dimensions and measure fluid flow over the denticle surface on both engineered models and living animals. In this presentation we provide an overview of our recent work on three-dimensional skin surface imaging on a diversity of shark species and body locations using gel-based stereo profilometry, and summarize ongoing experiments that measure the effect of surface roughness on (1) denticle models mounted on airfoils to quantify their effect on lift and drag, (2) experiments on the propulsion of 3D-printed biomimetic shark skin flexible foils, and (3) flow over the denticle surface in living sharks. Surface roughness in smooth dogfish varied from 9 to 42 µm and particularly interesting transitions in denticle shape and roughness were observed on the skin over the gills and on the fins and tail. Denticles mounted on a NACA 0012 airfoil increased the lift-to-drag ratio by up to 323%, and corroborate biomimetic shark skin experiments demonstrating that denticle surfaces are capable of both reducing drag *and* enhancing thrust. Experiments on the propulsion of flexible shark skin membranes also show that denticle-containing surfaces are capable of both increasing self-propelled speed and reducing the cost of transport. Thrust enhancement by roughened denticle surfaces is an underappreciated aspect of shark skin, as almost all previous studies have focused on static drag reduction.

78-2 LAVERGNE, SG*; SEGUIN, J; BOUDREAU, M; MURRAY, D; KREBS, CJ; MCGOWAN, PO; BOONSTRA, R; Univ. of Toronto, Trent University, Univ. of British Columbia; *sophia.lavergne@mail.utoronto.ca*
Neurobiology of risk: Prenatal effects of predation risk in snowshoe hares
The population dynamics of snowshoe hares (*Lepus americanus*) are fundamental to the ecosystem dynamics of the North American boreal forest, an ecosystem that covers more than half of Canada's land mass. During their 8-11 year population cycle, hare densities can fluctuate up to 40-fold. The cycle is driven by predators (lynx, coyotes, great-horned owls) that affect hare demography not only through direct mortality but also through non-consumptive effects on reproduction and survival that are mediated by chronic stress. In addition to individual effects, predator-induced stress during pregnancy can act through the mother on her developing offspring, creating the potential for large-scale population effects if all individuals in the population are similarly affected. We investigated the prenatal effects of predation risk during pregnancy in two ways. First, by experimentally increasing predator encounters in an "unstressed" natural population of hares (increase phase, low predator density) using targeted chases of radio-collared pregnant hares by a mammalian predator (domestic dog). Second, by observing change as function of the natural increase in predator density that occurred from the increase to the peak phases of the hare cycle. We found a suite of coordinated gene expression changes in the brains of offspring born to prenatally-stressed mothers. Transcriptional activity of corticosteroid receptor and co-chaperone genes involved in regulating HPA axis function produced a stress-sensitive, neuroresilient offspring phenotype, that could confer early-life survival advantages in an increasingly predator-abundant world.

P1-128 LAVIN, SR*; WHEATON, CJ; MYLNICZENKO, ND; Disney's Animal Kingdom, Orlando, FL; *shana.lavin@disney.com*
Is a GnRH Vaccine an Effective Contraception Method in Zoo-Managed Mammals?
Effective contraception plays a critical role in collection plans for zoo species. Permanent methods to control reproduction often are not suitable options, and short-term contraceptive efforts (e.g., synthetic progestins) have proved challenging. A promising alternative method for use in both sexes is a gonadotropin-releasing hormone (GnRH) immunocontraceptive vaccine. This vaccine has been used successfully for population control in a variety of wild and domestic mammalian species. We tested the efficacy of the GnRH vaccine GonaCon™: USDA in Nile hippopotamuses, (n=2♀, 1♂) or Improvest®: Zoetis US in red river hogs (n=2♀), large flying foxes (n=12♂), Nubian goat (n=1♀), warthogs (n=2♀), and reticulated giraffe (n=1♀). Animals were injected subcutaneously 1-3 times with the vaccine using empirical doses. Serial injections were separated by at least four weeks. Before and after vaccine administration, we measured fecal testosterone and progesterone in males and females, respectively, using enzyme immunoassays. Results were highly variable depending on species and/or course of treatment. For example, treatment was effective in all species tested with the exception of warthogs and giraffe. Bats were suppressed but had negative vaccine reactions following a single injection of the vaccine. All other species required multiple doses to suppress patterns of gonadal steroids. GnRH vaccines have potential for contraceptive treatment in zoo mammals. Health and hormone monitoring, however, is needed in species previously untested to assess safety, efficacy, reversibility, and the need for booster injections.

P3-12 LAVINE, M.D.; HAYES, A.M. *; ZINNA, R.S.; GOTOH, H.; EMLEN, D.J.; LAVINE, L.C.; Washington State University, Mars Hill University, Hokkaido University, University of Montana; *abigail.hayes@wsu.edu*
Uncoupling horn growth from body size in the Asian rhinoceros beetle
The Asian rhinoceros beetle *Trypoxylus dichotomus*) represents one of the best examples of exaggerated trait growth. Males of this species have extraordinarily large head horns with respect to body size, which they use in male-male competition for access to females. These horns grow out of scale to body size so that large males have horns much larger than would be expected based on their overall body size. We have previously found that the insulin receptor mediates the exaggerated growth of these sexually dimorphic, condition-dependent horns but does not account for horn allometry. Here we use RNAi to examine the role of other genes that function in horn growth. We have identified several genes, both from the insulin-signaling and other pathways, that appear to be involved both in overall horn growth, and more specifically in mediating the scaling of horn length to overall body size.

18-2 LAW, CJ*; MEHTA, RS; Univ. of California, Santa Cruz; *cjlaw@ucsc.edu*

Carnivory maintains cranial dimorphism between males and females: Evidence for niche divergence in extant Musteloidea

The evolution and maintenance of sexual dimorphism has long been attributed to sexual selection. Niche divergence, however, serves as an alternative but rarely tested selective pressure also hypothesized to drive phenotypic disparity between males and females. We reconstructed ancestral social systems and diet and used Ornstein-Uhlenbeck (OU) modeling approaches to test whether niche divergence is stronger than sexual selection in driving the evolution of sexual dimorphism in cranial size and bite force across extant Musteloidea. We found that multipeak OU models favored different dietary regimes over social behavior and that the greatest degree of cranial size and bite force dimorphism were found in terrestrial carnivores. Because competition for terrestrial vertebrate prey is greater than other dietary groups, increased cranial size and bite force dimorphism reduces dietary competition between the sexes. In contrast, neither dietary regime nor social system influenced the evolution of sexual dimorphism in cranial shape. Furthermore, we found that the evolution of sexual dimorphism in bite force is influenced by the evolution of sexual dimorphism in cranial size rather than cranial shape. Overall, our results highlight niche divergence as an important mechanism that maintains the evolution of sexual dimorphism in musteloids.

P1-37 LAW, CJ*; DURAN, E; HUNG, N; RICHARDS, E; SANTILLAN, I; MEHTA, R; Univ. of California, Santa Cruz; *cjlaw@ucsc.edu*

Cranial shape differences do not translate to bite force differences between musteloids with distinct dietary ecologies

Size and shape are often considered important variables that lead to variation in performance. In studies of feeding, size-corrected metrics of the skull are often used as proxies of biting performance; however, few studies have examined the relationship between cranial shape in it's entirety and estimated bite force across species and how dietary ecologies may affect these variables differently. Here, we used geometric morphometric and phylogenetic comparative approaches to examine relationships between cranial morphology and estimated bite force in the carnivoran clade Musteloidea. We found a strong relationship between cranial size and estimated bite force but did not find a significant relationship between cranial shape and size-corrected estimated bite force. Many-to-one mapping of form to function may explain this pattern because a variety of evolutionary shape changes rather than a single shape change may have contributed to an increase in relative biting ability. We also found that dietary ecologies influenced cranial shape evolution but did not influence cranial size nor size-corrected bite force evolution. While musteloids with different diets exhibit variation in cranial shapes, they have similar estimated bite forces suggesting that other feeding performance metrics and potentially non-feeding traits are also important contributors to cranial evolution. We postulate that axial and appendicular adaptations and the interesting feeding behaviors reported for species within this group also facilitate different dietary ecologies between species. Future work integrating cranial, axial, and appendicular form and function with behavioral observations will reveal further insights in the evolution of dietary ecologies and other ecological variables.

P2-123 LAZENBY-CHOI, M*; RUBIN, AR; WADA, H; Auburn University; *mpl0011@auburn.edu*

Effects of Incubation Temperatures on Beak Coloration Development in Zebra Finches

Developmental environment can have a strong influence on phenotype of offspring. In birds, embryonic development is a crucial life history stage with incubation temperature playing a large role in determining individual phenotype. Incubating parents will modify their incubation behavior depending on their body condition and ambient temperature by exposing eggs to suboptimal temperatures. Many studies have assessed the effects of constant suboptimal incubation temperatures on phenotype, but little is known about how fluctuating incubation temperatures alter offspring phenotype. Similarly, only few studies have investigated long-term effect of incubation temperature on fitness-related measures. One fitness related trait in birds is beak coloration, a secondary sex characteristic that indicates health condition and influences successful mating for both males and females, which varies with age and sex. Here, we assessed how periodic cooling during embryonic development influences the development of beak coloration as zebra finches (*Taeniopygia guttata*) reach sexual maturity. Embryos were incubated at one of the three temperature regimes; constantly low (36.4°C), periodic temperature (average 36.4°C), and control (37.4°C) temperatures. The hue, intensity, and saturation of the beak color was then recorded every 15 days from post hatch day 45 to 90. In *T. guttata*, juveniles have dark black beaks which become bright red in males or bright orange in females. Differences in the rate of development of this coloration between treatments, and between sexes within a treatment may indicate sex specific responses to suboptimal incubation temperatures.

24-5 LÓPEZ-CERÓN, A*; BUNTING, N; MYKLES, D; Colorado State University; *alopcer@rams.colostate.edu*

Effects of temperature and molt stage on the expression of stress-response genes in the Y-organ of the blackback land crab, Gecarcinus lateralis

Molting in decapod crustaceans is controlled by ecdysteroid synthesis in the Y-organ (YO). Environmental stressors may inhibit molting by reducing YO ecdysteroidgenesis through altered expression of stress-response genes that maintain physiological stability. Stress response genes regulate the energy relocation in normal and extreme conditions. The purpose of this study was to quantify the effects of molt stage and elevated temperature on hemolymph ecdysteroid titer and AMPK, heat-shock protein (HSP), and Sirtuin (SIRT) gene expression in the YO of *G. lateralis*. Individuals were induced to molt by multiple leg autotomy. YO of animals at 27°C was harvested at intermolt; early, mid, and late premolt; and postmolt stages. Individuals at the five molt stages were exposed to 32 and 35°C for 1 hour. mRNA level was quantified by qPCR. Ecdysteroid was quantified by a competitive ELISA. In general, molt stage had no effect on gene expression at 27 and 32°C. Animals from intermolt through mid premolt and postmolt stages at 35°C showed lower mRNA levels of all genes. AMPK was significantly downregulated in intermolt, early and mid premolt, and postmolt individuals at 35°C. Late premolt crabs exposed to 35°C had higher HSP60, HSP70, and SIRT1 mRNA levels. At 35°C, altered gene expression in early and mid premolt may delay molting by reducing ecdysteroid synthesis in the YO. These data suggest that land crabs can tolerate 1-hour exposures at 32°C without eliciting a stress response at the transcriptional level. Future work will examine the effects of temperature on the phosphorylation of stress proteins. Supported by NSF (IOS-1257732).

P2-48 LE, DA*; COOK, TA; BUSCHBECK, EK; University of Cincinnati, Wayne State University School of Medicine, Detroit; *le2da@mail.uc.edu*

Extended electroretinogram (ERG) analysis to probe for genetically induced photoreceptor deficiencies in Drosophila melanogaster

Extracellular electroretinograms (ERGs), which measure the neuronal response of the retina to light stimuli, have been widely used to examine proper functioning of photoreceptors. ERGs have shown deficiencies resulting from the knockdowns of the gliogenic transcription factor *pros* in *Drosophila melanogaster* Semper cells, which are eye-intrinsic glial cells that reside adjacent to the photoreceptors. In contrast, Semper-cell specific knockdown of the transcription factor *dPax2* showed no deficiency, even though histologic analysis revealed highly disrupted eye morphology in such flies. In the preceding study, ERGs were measured in response to individual light pulses. Here, we developed two additional extensive light stimulation protocols: the "flicker fusion frequency" test and the "extended sequence" test. In the former test, flickering light stimuli of different frequencies were presented until we found the "fusion frequency" for which photoreceptors respond to the flickering pulses as if they were one prolonged pulse. In the "extended sequence" protocol, multiple repetitions of short light pulses were presented over several minutes to evaluate if photoreceptors were able to sustain consistent responses. Using these protocols, we revealed that Semper-cell knockdowns of *dPax2* showed a significant weakening of responses to later-presented light stimuli in the extended sequence. Our evidence suggests that photoreceptors in these knockdowns may not be able to maintain efficient energy supply from their associated Semper cells, and hence proper *dPax2* function also appears to play a role in homeostatic support for the photoreceptors. Our findings highlight the importance of characterizing physiological performance under a variety of different stimulus protocols.

125-6 LE GALL, M*; THOMPSON, N; CEASE, AJ; LE GALL, Marion; Arizona State University; *marionlegall314@gmail.com*

Cheating on Atkin's: high-protein diet reduces lifespan in the Senegalese locust, Oedaleus senegalensis.

Since the 1970's *Oedaleus senegalensis* has become and remains the most prominent pest of millet, a subsistence crop, in the Sahel region of Africa. A handful of studies have demonstrated that, unlike most herbivorous insects that are nitrogen (~protein) limited, some locust species prefer and perform better on carbohydrate-biased foods. We tested *O. senegalensis* nutritional preference and performance on foods varying in their protein: carbohydrate ratios. We ran experiments both in the laboratory, using artificial diets, and in the field where we modified the nutritional content of millet with two levels of fertilization using urea as a source of nitrogen. Our results show that, unlike predicted by the nitrogen limitation hypothesis, *O.senegalensis* prefers artificial food and millet leaves with a lower protein content. In the field, we found that locusts that were fed unfertilized millet lived longer than the ones fed millet grown with high or medium level of fertilizer. However, the mass of the eggs laid on the high fertilization treatment was higher than for the control plot that did not receive urea, suggesting a nutritional trade-off between lifespan and reproduction.

63-5 LEACH, W.B.*; REITZEL, A.M.; University of North Carolina at Charlotte; *wroger11@uncc.edu*

Transcriptome Dynamics After Light Removal in a Model Cnidarian

Circadian clocks are well understood in many bilaterian organisms where they regulate behavior and physiology through differential expression of hundreds of genes over daily and seasonal time. However, we have a rudimentary understanding of the antiquity and function of these clocks for earlier diverging lineages, including cnidarians. The sea anemone, *Nematostella vectensis*, is an emerging model for cnidarian circadian biology and previous studies have demonstrated rhythmic behavior that coincides with light-dependent expression of candidate circadian genes. To further characterize the role light plays in entraining circadian rhythms in this species, we used tag-based RNAseq to generate 136 transcriptomes from animals sampled over three days during four light regimes (12h:12h light:dark, 1 and 2 days post light-removal, and constant darkness) treated as ‘light conditions'. Weighted gene co-expression network analysis identified unique co-regulated gene modules differentially expressed between all light conditions. In the first 24-hour period of light removal, *N. vectensis* exhibited a 3-fold increase in the number of differentially expressed genes, particularly those involved in chromatin organization, as well as key members of the oxidative stress and metabolic pathways. Additionally, genes previously described as ‘circadian' were down-regulated in the absence of light and appear to lose rhythmicity immediately following light removal. Interestingly, the second day of light removal resulted in an entirely new set of differentially expressed genes compared with other light conditions. These data highlight the molecular complexity resulting from photoperiodic variability and, for the first time in cnidarians, suggests genes commonly referred to as ‘circadian' may be better described as photoresponsive.

P1-88 LEBENZON, JE*; MOHAMMAD, L; MATHERS, KE; TURNBULL, KF; STAPLES, JF; SINCLAIR, BJ; Western University, London, Canada, Univ. of Calgary, Calgary, Canada; *jlebenzo@uwo.ca*

Burning Down the Powerhouse: Does Mitophagy Drive Metabolic Suppression During Diapause in the Colorado Potato Beetle (Leptinotarsa decemlineata)?

Temperate insects spend over half their lives overwintering, during which most enter diapause; a pre-programmed state of developmental arrest. One of the most consistent physiological changes associated with diapause is metabolic suppression. All diapausing insects suppress their metabolic rates, but we have a limited understanding of what drives this metabolic suppression. Some insects degrade their muscles during the winter, however we do not know the extent to which this degradation contributes to metabolic suppression, especially at the mitochondrial level. In this study, we investigated the physiological mechanisms that drive metabolic suppression during diapause in the Colorado potato beetle (CPB), which suppress their metabolic rate by ~88% during diapause. We found that there is a gradual suppression of mitochondrial respiration rate as CPB enter diapause, and those in diapause have virtually undetectable respiration rates. This is, in part, driven by the breakdown of mitochondria in flight muscle, which we confirmed using MitoTracker staining, transmission electron microscopy, and citrate synthase enzyme assays. Furthermore, diapausing CPB show increased expression of *parkin* (a kinase involved in tagging mitochondria for removal), decreased expression of *atg5* (an autophagy-related protein involved in later stages of mitochondrial removal), and no change in mitochondrial biogenesis gene expression. These results suggest that mitochondria are tagged, but not fully disposed of during diapause in CPB, resulting in a decrease in functional mitochondria and suppressed metabolism. This study will help contribute to our understanding of how insects regulate mitochondrial abundance and function, and provide new insights into the mechanisms underlying diapause and metabolic suppression.

61-6 LEDBETTER, NM*; BONETT, RM; university of tulsa; *nil122@utulsa.edu*

Terrestrial Constraint on Salamander Limbs Sheds Light on Tetrapod Evolution

Patterns of phenotypic evolution can abruptly shift as species move between adaptive zones. Salamanders have frequently transitioned across three distinct life cycle strategies that range from aquatic-to-terrestrial (biphasic), to fully aquatic (paedomorphosis), to fully terrestrial (direct development). These transitions are often associated with changes in body form such as loss of digits, limb reduction, or body elongation. However, the relationships among these traits remain unresolved. Here we use an evolutionary modeling approach to test whether life cycle transitions in salamanders have influenced rates, optima and integration of primary locomotory structures (limbs and trunk). We show that paedomorphic salamanders have elevated rates of limb evolution with optima shifted toward smaller size and fewer digits compared to all other salamanders. Rate of hindlimb digit evolution is shown to decrease in a gradient as life cycles become more terrestrial. Paedomorphic salamanders exhibit reduced correlations between limb lengths as well as between forelimb digit loss and vertebral number. Paedomorphs have a higher correlation between hindlimb digit loss and increases in vertebral number. Our results generally demonstrate constraint on limb evolution due to terrestrial locomotion that, when lifted, leads to higher rates of trait evolution and shifts in optima and integration. The basic tetrapod body form of most salamanders and the independent losses of terrestriality life stages provide an important framework for understanding the evolutionary and developmental relationships between the limb skeleton and vertebral column.

80-6 LEE, A. B.*; SELEB, B.; HANLON, L.; SUN, A.; HU, D. L.; Georgia Institute of Technology; *ablee@gatech.edu*

Preventing bubble pinch-off in underwater sniffing

The star-nosed mole can sniff underwater by rapidly blowing and inhaling bubbles. How these moles manipulate bubbles without losing them is poorly understood. In this experimental study, we investigate the first phase of this underwater sniff, blowing the bubble. We conduct bubble formation experiments with a downward nozzle, inspired by the star-nosed mole. As the flow rate increases, the lifetime of the bubble before pinch-off decreases according to the scaling law $T \sim Q^{-2/3}$. The retarded decrease in duration is explained by the significant surface deformation and added mass that the bubble experiences as it expands through the gaps of the star. Understanding the fluid dynamics of underwater sniffing provides insight into the physiological requirements necessary to perform underwater olfaction.

105-6 LEE, D/V*; ISAACS, M/R; University of Nevada, Las Vegas; *david.lee@unlv.edu*

Does the Cost of Bipedal Walking Increase as the Square of Speed?

Bipedal walking is a particularly economical gait for humans and it is conventionally modeled by the inverted-pendulum construct of a rigid leg tracing a circular arc. At slow to moderate walking speeds, this model predicts low mechanical cost of transport (CoT-mech), which is determined by the impulse needed to reverse the downward velocity at the end of each arc. At moderate to fast walking speeds, however, CoT-mech is predicted to increase precipitously. An analytical solution for CoT-mech of the inverted-pendulum model predicts CoT-mech to increase as a squared function of speed. However, our experimental data from ten human subjects across a full range of walking speeds contradict the predictions of the inverted-pendulum model and show that human walkers exhibit only a moderate increase in CoT-mech with increasing speed. We use multiple regression to determine a function relating CoT-mech to both speed and the square of speed — in normalized terms, the square root of Froude number and Froude number. CoT-mech of walking humans was found to increase as a quadratic function of speed, having a positive squared term and a negative linear term. Using values of step length and velocity from our human data set, the analytical solution for an inverted-pendulum model shows the same squared term but yields a positive linear term. Expressing the linear term as a fraction of the squared term, gives -0.73 for the experimental CoT-mech and 0.31 for the analytical solution. Hence, the linear term in the simple inverted-pendulum model adds to the squared increase, whereas in walking humans, the linear term subtracts from the squared increase. Overall, the change in CoT-mech across the human walking speed range shows only a 1.5-fold increase, compared to the 9-fold increase predicted by the conventional inverted-pendulum model.

P2-91 LEFAUVE, MK*; HERNANDEZ, LP; George Washington University; *mlefauve@gwu.edu*

Invasive Correlated Behavioral Traits in Cypriniform Fish

Behavioral syndrome is a suite of correlated behaviors that are expressed within a given context (or across contexts) as correlations between activity levels and boldness in foraging and anti-predator contexts. Assessments of behavioral syndrome have suggested that some of these correlated behavioral traits such as boldness and activity, allow for comparisons in these traits between species in similar contexts. A species' ability to invade novel habitats could be linked to some of these flexible correlated behaviors. This study looked at behavioral syndrome in fish species considered to be invasive or potentially invasive and species not considered to be invasive to determine if there is indeed a behavioral syndrome which appropriately characterizes "invasiveness". Using validated tasks such as shelter latency and scototaxis, we determined species' boldness in complex environments, exploratory behavior, latency to explore a novel environment, and activity in both a novel and familiar environment. Preliminary data suggests that species that are noninvasive are more active in a familiar environment ($p<0.01$) but seem to be less exploratory when in a novel or fearful environment ($p<0.05$). These results suggest that there are a series of correlated behavioral traits that can aid in invasion of novel ecosystems by fish species. While several studies have investigated morphological and physiological adaptations associated with invasive species, relatively few studies have examined the behavioral syndromes that may characterize these dangerous species.

113-3 LEIGH, SC*; GERMAN, DP; University of California, Irvine; *scleigh19@gmail.com*

The Role of Microbial Symbionts in Bonnethead Shark Seagrass Digestion

Sharks, uniformly accepted as carnivores, have guts specialized for a high-protein diet. However, the bonnethead shark (*Sphyrna tiburo*) has been shown to consume copious amounts of seagrass (up to 62.1% of gut content mass). Bonnetheads were found to digest 51.2% of the organic matter in seagrass, as well as possess cellulose-component-degrading enzymes (β-glucosidase) in their hindguts. This indicates likely involvement from the gut microbiome as part of the seagrass digestion process. In order to understand the role that the microbiome plays in bonnethead shark seagrass digestion, gut contents and mucosal scrapings were collected along the digestive tract of wild-caught bonnetheads (n=4) and bonnetheads that were fed a 90% seagrass and 10% squid diet in the lab (n=5). Using 16s rDNA sequencing, we determined the taxa of microbes present along the bonnethead shark digestive tract. Using gas chromatography of gut content fluid, we determined the concentrations of short-chain fatty acids, the primary end-products of microbial fermentation, in the different gut regions. Data collection is in progress. Results of this work show that the bonnethead shark is digesting seagrass at higher efficiency than would be expected for a "carnivore," and digestion may be aided by microbial symbionts. These findings have ecological implications because they show that bonnethead sharks are omnivorous and play a different role (including nutrient transport) than assumed within fragile seagrass ecosystems.

P2-263 LENARD, A*; PEREZ, A; DIAMOND, SE; Case Western Reserve University; *angie.lenard17@gmail.com*

Urban nighttime-biased warming alters growth and developmental trajectories throughout ontogeny in a cosmopolitan butterfly species

It is well established that mean temperatures are rising; however, rates of warming are not equal spatially or temporally. Cities create "urban heat islands" and the pattern of diel warming is often asymmetrical. Rises in nighttime temperatures contribute more to mean temperature change than rises in daytime temperatures. However, the biological consequences of such nighttime-biased warming are largely unknown. In this study, we examined how nighttime-biased warming affects the growth and development of painted lady caterpillars (*Vanessa cardui*), a widespread butterfly species, throughout ontogeny. We reared animals under one of six diurnally fluctuating temperature treatments: three treatments represented typical diurnal fluctuations in summer temperatures, including an average day, a warm day, and a cool day; the three remaining treatments modified these diurnal fluctuations such that the warming was biased towards the nighttime, but with comparable daytime temperatures. We also compared the effects of these fluctuating temperature treatments against chronic warming treatments with the same mean temperature. We recorded the body mass of caterpillars at each larval instar, at metamorphosis (pupation), and upon eclosion as adults, and we recorded the development time (in days) to each developmental stage. Our results indicate consistent acceleration of development time under nighttime-biased warming regimes; however, the effect of nighttime-biased warming on body mass throughout ontogeny was more idiosyncratic.

95-1 LENARD, A*; GIFFORD, ME; University of Central Arkansas; *angie.lenard17@gmail.com*

Effects of early-season maternal lipid consumption on reproductive strategy and embryonic development in the prairie lizard, Sceloporus consobrinus

Maternal effects, such as stress, body condition, and hormone levels have been shown to affect female reproductive strategies and offspring phenotype. The overall quality of maternal diet has been shown to affect reproductive investment and timing of clutch production in some lizards. However, few studies have explored the effects of a specific macronutrient on reproduction. In this study, we examined the effects of early-season maternal lipid consumption on reproductive investment and embryonic development in prairie lizards. We captured female prairie lizards from an Arkansas population soon after overwinter emergence. Females were fed *ad libitum* either a high-lipid diet of 3 waxworms (14.8% lipid) or a low-lipid diet of 5 crickets (2.5% lipid). We monitored the number of prey items consumed until females were vitellogenic, upon which they were paired with a mate. We also monitored female body compositions from capture through oviposition with weekly quantitative magnetic resonance scans. After oviposition, we recorded clutch size, egg mass, and maternal lipid loss, as a proxy for lipid investment. All eggs were incubated under common conditions. Upon hatching, we recorded incubation duration and hatchling mass and snout-vent length. This study suggests that early-season, high-lipid diets influenced some reproductive investment traits, but not those pertaining to hatchling phenotypes. These data are generally consistent with theories that first clutches are produced from capital reserves.

70-4 LENCER, ES; University of Colorado Anschutz Medical Campus; *el468@cornell.edu*

Modifications to cell proliferation underlie differences in craniofacial phenotype between closely related species (genus: Cyprinodon)

Understanding the genetic basis for phenotypic differences is fundamental to the study of macroevolutionary patterns of biological diversity. While technological advances in DNA sequencing have made researching genetic variation in wild taxa routine, fully understanding how these variants affect phenotype usually requires taking the next step to investigate how genetic changes alter cell and tissue interactions that ultimately produce phenotypes. Here, I report on data suggesting a role for cell proliferation as a developmental source of craniofacial morphological diversity in a radiation of three species of *Cyprinodon* from San Salvador Island, Bahamas. Patterns of cell proliferation in the heads of hatching-age fish differ among species of *Cyprinodon*, and correlate with differences in allometric growth rate among the jaws of three distinct species. Regional patterns of cell proliferation in the head are complex resulting in an unintuitive mechanism by which lower levels of proliferation lead to growth of relatively larger jaws. I combine these data with previously published morphological and genomic data to show how studying the mechanisms generating phenotype at the cellular and tissue levels of biological organization can help mechanistically link genomic studies with classic morphological studies.

P3-141 LENGA, SH*; CIRINO, LA; MILLER, CW; University of Florida; *sarah.h.lenga@ufl.edu*

Effects of Autotomy on Sperm Depletion in Narnia femorata

The classical understanding of male reproductive costs may overestimate male reproductive resource capacity. Understanding the limits of male reproduction helps us understand the selection pressures on male reproductive phenotypes and how these phenotypes may persist in a population. There is evidence to suggest that *Narnia femorata* may suffer from sperm depletion. Furthermore, the loss, or autotomy, of a hind leg weapon during the juvenile stage of an *N. femorata* promotes the growth of larger testes. The objective of this study was to understand the extent to which sperm depletion is occurring in *N. femorata* and if enlargement of the testes through autotomy mitigated this depletion. I addressed these objectives by quantifying hatching success from females mated with virgin and multiply mated males that either had or had not autotomized one of their hind legs during development. Preliminary analyses suggest hatchling number and hatchling success decline as the number of previous matings by males increased. We predict that autotomized males will experience a more subtle decline in hatchling number and hatching success with increased matings when compared to their intact counterparts. This study will resolve whether or not males who have lost a pre-copulatory weapon are better equipped to compete in a post-copulatory context.

43-5 LEON, AE*; HAWLEY, DM; Virginia Tech, Blacksburg; *leona@vt.edu*

Host immunity and selection on pathogen virulence in a songbird-bacterium system

Few natural systems have provided the opportunity to empirically test the theory that incomplete host immunity selects for higher pathogen virulence. Since its emergence in North American house finch populations, the bacterial pathogen *Mycoplasma gallisepticum* (MG) has increased in virulence. Previous work has demonstrated that repeated low-dose exposure to MG, a proxy for what birds may experience at feeders, provides significant but incomplete protection against secondary infection and produces a within-host environment that favors more virulent strains. Here we sought to determine if previous exposure level mediates the transmission potential of a host, and if this favors the transmission of more virulent strains. To test this, we first created variation in prior exposure by exposing captive, wild-caught house finches to one of two priming exposures of MG, which varied by dose and total number, or to a media-only control. After recovering from priming exposures, individuals were inoculated with a single high dose of a strain of equal or higher virulence and paired with an MG-naïve cage-mate to assess pairwise transmission potential. Immunity from prior exposure significantly reduced the pairwise transmission potential of individuals, with the lowest transmission potential in house finches which were given high-dose priming exposures. The more virulent strain had higher overall transmission potential than the less virulent strain, but again this varied with host exposure history. Interestingly, individuals that received low-dose priming exposures, which prior work showed generate largely incomplete immunity in house finches, showed identical transmission potential between pathogen strains. Together these results demonstrate that host immunity, mediated by exposure history, can significantly alter the transmission potential of an individual.

P2-97 LEPIANE, K/L*; CLARK, C/J; University of California, Riverside; *klepi001@ucr.edu*

Silent flight and the hunting strategy of the Common Poorwill (Phalenoptilus nuttallii)

Common Poorwills (*Phalaenoptilus nuttallii*) are nocturnal insectivorous birds that have a sit-and-wait predation strategy. They wait for an insect to fly overhead, then fly up and catch it in their beak. *P. nuttallii* have several wing and feather features that are hypothesized to reduce their locomotion-induced sounds, aiding in silent flight. These specialized features include a velvety dorsal surface and vane fringe, both present on flight feathers. There are two hypotheses for the evolution of silent flight: prey detection and stealth. The prey detection hypothesis predicts that silent flight evolved to reduce the sounds generated by locomotion, improving a predator's ability to acoustically locate prey. The stealth hypothesis predicts silent flight evolved to help predators launch surprise attacks. The prey detection hypothesis predicts that the predator relies on auditory cues to hunt. However, *P. nuttallii* is not known to hunt acoustically and their eye morphology and hunting behavior suggest that they may be primarily visual hunters. Therefore, we hypothesize that silent flight evolved in *P. nuttallii* to aid in stealth. Silencing features may reduce ultrasound by dampening the sounds produced when two feathers rub together, allowing *P. nuttallii* to avoid detection by hearing insects while hunting. We assess hypotheses of how flying insects may detect an approaching predator, and how likely it is that silencing features present on *P. nuttallii* wings aid in a stealthy hunting strategy. We recorded *P. nuttallii* hunting in the wild with an infrared camera to quantify their feeding behavior and the behavior of their intended prey during an attack.

S1-3 LESLIE, Andrew B.*; LOSADA, Juan M.; Brown University; *andrew_leslie@brown.edu*

Functional Ontogeny and Morphological Evolution in Plant Reproductive Structures

Form and function relationships are most often evaluated with regards to static functional roles, but these relationships may change over the lifetime of an organism or even its component parts. For example, flowers initially function in pollen transfer, but subsequently, as fruits, they protect and release seeds. Meeting such disparate demands often requires complex patterns of ontogenetic shape change, and in such organisms, any given form and function relationship could be thought of as a temporary stop along a larger developmental trajectory. Differences in specific developmental patterns among lineages may therefore play an important role in shaping and constraining form and function relationships and determining broader patterns of evolution. We explore these possibilities using conifer seed cones in the Pinaceae family, which are highly integrated structures that sequentially perform three basic functional roles: they facilitate wind pollination, they protect maturing seeds, and they disperse mature seeds. We combine anatomy, functional morphology, and phylogenetic comparative methods to show that cone phenotypes reflect a complex interplay between development and functional demands. Variation in developmental rate and timing alone can generate morphological diversity among lineages during some functional stages, such as at pollination. On the other hand, seed dispersal in Pinaceae occurs through a few mechanisms dictated by seed size, packing density, and dispersal agents, which constrain cone development patterns after pollination. Complex functional ontogenies are also present in many other plants, suggesting that interactions between developmental patterns and functional morphology may shape patterns of reproductive evolution across many lineages.

P2-45 LESLIE, CE*; ROSENCRANS, RF; BAZAN, NG; FARRIS, HE; Univ. of Texas, Austin, Louisiana State University School of Medicine, New Orleans; *cleslie@utexas.edu*

Hormonal Modulation of Retinal Sensitivity in a Neotropical Frog

Visual cues are often a vital part of animal communication and courtship. While a plethora of studies have focused on the role that hormones play in acoustic communication of anurans, relatively few have explored hormonal modulation of vision in these animals. Much of what we do know comes from behavioral studies, which show that a frog's hormonal state can affect both its visual behavior and mating decisions in significant ways. However, to fully understand how frogs use visual cues to make these mating decisions, we must first understand how their visual system processes these cues, and how hormones affect these processes. To do this, we performed electroretinograms (ERGs) to determine the retinal sensitivity of the túngara frog (*Physalaemus pustulosus*), a neotropical species whose mating behavior includes previously described visual cues. We performed ERGs for both scotopic and photopic conditions. Tested frogs were either non-reproductive or hormone-treated with human chorionic gonadotropin (HCG) prior to testing to determine the effect of hormonal state on visual sensitivity.We found that both sexes display higher visual sensitivity under scotopic conditions compared to photopic conditions. In addition, hormone injections significantly increased visual sensitivity of females under scotopic conditions. These results not only support behavioral findings regarding visually-guided behavior in this species, but also serve as a starting point for elucidating the mechanism of hormonal modulation of visual sensitivity.

114-3 LEVELL, ST*; REZNICK, DN; Univ. of California, Riverside; *sleve004@ucr.edu*

Can Females Differentially Allocate Resources to Offspring Sired by Different Males?

The Viviparity-Driven Conflict Hypothesis (VDCH) predicts that the placenta provides a novel arena for conflict over resources. Parent-offspring conflict is a predicted to occur because the optimal quantity of resources for an offspring to get from its mother is more than is in the best interest of the mother to provide. This conflict is exaggerated if females' mate with multiple males. 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. Alternatively, the offspring of males from foreign populations may be better (or worse) at acquiring resources from their mother. *Heterandria formosa*, a placental fish, is particularly suited to test the predictions of the VDCH because their populations exhibit dramatic differences in offspring size. In this experiment, females from either large-offspring producing or small-offspring producing populations were artificially inseminated with a combination of sperm from males originating from their own population, a different population, or both. Additionally, treatments consisted of either two or four males to determine whether mating with multiple males affects offspring number or size within and among broods. Our results suggest that the paternal population dictates offspring size in uni-directional crosses. However, when sperm is mixed from multiple populations of males, the size of the resulting offspring depends on how many males were used, and the resulting offspring size in these crosses is different depending on the female's population of origin.

P2-44 LEVENDOSKY, MW*; BEDORE, CN; Georgia Southern Univeristy, Georgia Southern University; *ml06458@georgiasouthern.edu*

Bioelectric potentials of shark prey are independent of body size

Elasmobranchs use electroreception to localize prey at short distances. While this sensory system has been well studied, the methods by which prey bioelectric fields are generated and the voltage and frequency characteristics of the bioelectric fields are less studied. Additionally, electroreception literature often states that prey body size is positively correlated with voltage, however, there is a complete lack of empirical evidence supporting this claim. Therefore, the goal of this study is to survey bioelectric potential strength across a range of sizes (length and mass) of invertebrate, teleost, and elasmobranch species. As previously reported teleosts possessed stronger electric potentials (361 ± 83.5 µV) than both elasmobranchs (99.7 ± 1.6 µV) and invertebrates (44.9 ± 8.0 µV), which is likely related to different osmoregulatory strategies used by these groups. Within each of these groups, there was no relationship with length/width or mass. However, among elasmobranchs batoids tended to have larger electric potentials than sharks. This difference may be attributed to the physical flow of water and the ions within it, or as a result of physiological osmoregulation that occurs at the gills. Therefore, future work will examine electric potentials within the context of these physical and morphological features (water volume, flow rate and gill surface area) of the respiratory organs.

134-4 LEVIN, II*; HUND, AK; IBRAHIM, AI; STEPHENS, JQ; WICKER, VV; TSUNEKAGE, T; MCCAHILL, K; SAFRAN, RJ; Agnes Scott College, University of Colorado - Boulder; *ilevin@agnesscott.edu*

Heritability of telomere length in nestling barn swallows (Hirundo rustica erythrogaster)

The natal environment can influence an organism's survival and reproductive success. Telomere length is demonstrated to co-vary with measures of organismal performance, and telomere dynamics early in life may have long-lasting consequences. Therefore, it is important to understand the sources of variation in telomere length. We investigated the relative contributions of genetic vs. environmental effects on variation in telomere length in nestling barn swallows (*Hirundo rustica erythrogaster*) using an egg-cross foster experiment. Half of the eggs in nests were switched with synchronously laid eggs from different nests. This design, and the fact that broods contain mixed paternity, allows us to decouple genetic and environmental effects on telomere length. Female incubation behavior was quantified with thermocouple eggs that record incubation temperature profiles. We measured relative telomere length of nine-day old nestlings using qPCR, assigned parentage of nestlings using microsatellite markers, and used an animal model to investigate heritability. A substantial amount of variation in telomere length could be attributed to additive genetic variance; however, the nest environment also explained a significant amount of overall phenotypic variance. 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. Our results support our hypothesis; eggs experiencing a higher mean temperature, especially early in incubation, resulted in nestlings with longer telomeres relative to nestlings from eggs incubated at lower mean temperatures.

P3-151 LEVY, O*; NORONHA, C; TELEMECO, RS; ANGILLETTA, MJ; Tel Aviv University, Tel Aviv, Israel, Federal University of Goias, Jatai, Brazil, California State University, Fresno, CA, Arizona State University, Tempe, AZ; *levyofi@gmail.com*
Metabolic Depression During Winter Could Mitigate Impacts of Climate Change on lizards
The impacts of climate change have been extensively studied in lizards. However, most studies have explored how warming may affect the potential for activity and subsequent growth and reproduction, while climate change may also affect overwintering lizards. In particular, although lizards may be able to begin activity and reproduction earlier under a warming climate, warmer winters will raise energy demands, increasing the risk of starvation and decreasing surplus energy for growth or reproduction. To better understand the energy demands of lizards during winter, we tested whether thermal acclimation of metabolism enables animals to save energy using a widespread group of lizards from the *Sceloporus undulatus* complex. In the lab, lizards from four populations were exposed to either a constant 12°C, a constant 2°C, or a linear decrease in temperature from 12°C to 2°C. After three weeks, we compared the metabolic rates of these when exposed to 2°C and 12°C to their rates prior to acclimation. Interestingly, lizards vary in their acclimation strategies based on their current climate. In particular, lizards from the relatively cooler populations (Colorado) reduced their metabolic rate only at the cooler temperature (2°C), and lizards from relatively warmer population (Arizona) reduced their metabolic rate only at the warmer temperature (12°C). Moreover, lizards from the population from New Jersey, which is characterized by an intermediate climate, reduced their metabolic rate under both 2°C and 12°C. These different levels of acclimation can affect the ability of lizards to mitigate impacts of global warming.

124-1 LEVY, G.*; TRIMMER, B.A.; Tufts University, Medford, Massachusetts, USA; *guy.levy@tufts.edu*
Realtime, 3-D Acquisition and Analysis of Caterpillar Locomotion
The kinematic parameters of crawling behavior in the caterpillar *Manduca sexta* are being studied to better understand the neuromechanics of soft bodied animal locomotion. We have developed a method to track and analyze the 3D movements of *Manduca* in real-time, while crawling on different substrates and in different orientations. This method is being used to determine which substrate parameters are sensed by the animal, and how it uses this sensory information to adjust its gait. *Manduca* movements are complex and variable, so real-time tracking allows detailed kinematic parameters to be analyzed to identify important statistical changes in large datasets. The method is based on a commercial device (Vicon), originally designed to capture human motion, and it reports the three-dimensional position of markers in the scene. To adapt this system for use on small (and soft) animals we have replaced the retroreflective markers with microscopic IR-LEDs. These are manually soldered to one another with a very fine wire to form a suit that is stitched onto the cuticle of the caterpillar. The caterpillar is then placed inside a circular treadmill that can be positioned in any orientation with respect to gravity and the Vicon cameras report the 3-D position of the LEDs. A custom-made, multi-layer parallel-processing Matlab software, working across several computers, acquires the Vicon data and analyzes it in realtime while also saving it for future, offline replay. With this system it is possible to quantify the movements of multiple body segments simultaneously and to detect small changes in the coordination of the crawling gait in response to environmental stimuli. Supported by NSF/IOS grant 1456471 awarded to Barry Trimmer.

22-3 LEWIS, AK*; COHN, MJ; University of Florida; *lewis23a@ufl.edu*
The anti-androgenic fungicide vinclozolin disrupts sexual differentiation of the external genitalia
In recent decades, there has been a rise of endocrine-related diseases and disorders, including genital malformations, low semen quality, adverse pregnancy outcomes, neurobehavioral conditions, cancers of reproductive organs, earlier onset of breast development, obesity, and type 2 diabetes (UNEP and WHO, 2013). For example, congenital penile anomalies (CPA) now affect 1 in 120, or 0.83%, of male newborns (Nelson et al., 2005). The most commonly reported CPA is hypospadias, which is characterized by mislocalization of the urethral opening along the penile shaft, within the scrotum, or in the perineum, with the most severe cases resulting in ambiguous genitalia. Our lab previously demonstrated that conditional deletion of the androgen receptor (AR) gene from mesenchymal cells of the mouse genital tubercle - the embryonic precursor to the penis and clitoris - induces penile anomalies that mimic human CPAs (Zheng et al., 2015). Moreover, the timing of AR disruption, whether by genetic or pharmacologic mechanisms, determines the type of CPA that arises, reflecting a critical window of susceptibility. Here we report that male mouse embryos exposed to vinclozolin, an environmental endocrine disruptor, during the same temporal window also develop external genital defects that mimic human CPAs. Dissection of the cellular and molecular mechanisms that mediate vinclozolin-induced hypospadias revealed disruption of fetal sex steroid levels and the distribution of their respective receptors. Furthermore, we find that the sexually dimorphic patterns of cell death and proliferation that occur during normal genital development are disrupted in treated mice. Taken together, these results suggest that transitory exposure to vinclozolin during the critical period of susceptibility causes genital malformations by abolishing male- and female-specific endocrine profiles and morphogenetic processes.

P1-15 LEWIS, AK; University of Florida; *lewis23a@ufl.edu*
Feminization of mouse male external genitalia and digit ratio: Inappropriate applications of gendered terms in sex biology
Biologists studying sexual dimorphisms often impose gendered terms (masculinize, feminize, etc.) onto morphological sex characteristics. Application of gendered descriptions to morphological characters and morphogenetic processes reinforces outdated notions of gender and sex. Genital development is a major focus of the study of sexual differentiation. In our experimental studies, we found that XY mouse embryos exposed to the anti-androgenic chemical vinclozolin at specific embryonic stages have a mislocated urethra. At birth, the urethra of VCZ-treated males is where the XX female urethra typically is. Biologists typically refer to this as "feminization," although urethral position is a morphological sex trait, not a gender trait. Another well-studied sexually dimorphic character is the ratio of second to fourth digit length (2D:4D ratio). In humans, the 2D:4D ratio has been shown to correlate with gender, sexual orientation, health, and behavioral traits. Men typically have 2D < 4D, while women typically have 2D > or = 4D. The same ratios are seen in male and female mice, respectively. It's been suggested that 2D:4D is reflective of fetal androgen exposure, and dimorphism in mouse 2D:4D is due to androgen/estrogen signaling in the 4th digit. Prenatal exposue to vinclozolin induces XY mice to develop XX-typical 2D:4D proportions. Previous work has referred to XY mice with XX-typical 2D:4D as "feminized". While appropriate for correlating gender with digit ratio, this is not an appropriate description of biological sex characters. I examined the frequency of gendered terms in PubMed entries and found that these terms are often inappropriately applied to animal and plant studies of sex. As biologists, it is our responsibility to improve our descriptions and terms.

S9-4 LEYS, SP*; MAH, JL; KAHN, AS; University of Alberta, Monterey Bay Aquarium Research Institute, Yale University; *sleys@ualberta.ca*

Sense and Sensitivity in Sponges: a functional and genomic view

What affects a sponge, what does it perceive and how does it detect and respond to these stimuli? Sponges are generally thought of as simple, but the array of stimuli they perceive and range of mechanisms of response are probably as diverse as the types of sponges that are known. Sponge larvae respond to light but opsins are not used, nor is there a common photoreceptor molecule or mechanism used across sponge groups. Other better-known cues are gravity and chemicals (e.g. molecules in algae or in other sponges or invertebrate symbionts). Adult sponges appear static but are in fact quite twitchy in their own time frame and one less studied stimulus may be change in pressure. The sensors for these cues as far as we know are individual cells, and these most likely act as independent effectors, and generate a whole body reaction by the global reach of the stimulus to all parts of the animal, except in the case of electrical signalling in Hexactinellida. Most surprising so far is that the molecular basis of all these systems appears to be as varied as the cell types and coordination mechanisms seen in sensory systems. This talk will examine examples of form, function, and their molecular basis across Calcarea, Demospongiae and Hexactinellida.

S1-6 LI, Fay-Wei; Boyce Thompson Institute; *fl329@cornell.edu*

Diversity and genetics of plant-cyanobacteria symbioses

Plant symbiosis with nitrogen-fixing cyanobacteria is a unique form of mutualistic association that has independently evolved in diverse lineages including a few species of bryophytes, ferns, cycads, and one small genus of flowering plants. Compared to other nitrogen-fixing microbes, cyanobacteria are generally less dependent on the plant host, and therefore could be an ideal partner for engineering symbiotic nitrogen fixation into crop plants. However, our current understanding of plant-cyanobacteria symbioses is rudimentary. The phylogenetic diversity of cyanobionts has been largely unexplored, and the plant genes involved in cyanobacterial symbiosis have remained unknown. Here I will present our ongoing work on cyanobacterial symbioses in ferns (Azolla) and hornworts. Using Illumina resequencing and PacBio amplicon-seq, we are beginning to characterize the cyanobiont diversity and examine plant-cyanobiont co-evolutionary history. In addition, several putative symbiosis genes have been identified through our comparative genomics and RNA-seq analyses.

127-7 LI, DH*; BARTOL, IK; GILLY, WF; Stanford University, Old Dominion University; *lidh@stanford.edu*

Hydrodynamic diversity in squid jets mediated by giant and non-giant axon systems

Giant and non-giant axon systems in squid can act individually or in concert to control a diversity of jet-propelled maneuvers. The giant system primarily underlies strong, stereotyped mantle contractions to form fast escape jets, whereas the non-giant system allows graded contractions that enable a wide range of swimming speeds. Swimming speed in turn predicts jet hydrodynamics where impulse increases with speed. Both systems expel water through the siphon, but the connection between neuromuscular control and hydrodynamic output has remained unexplored. We used simultaneous recordings of neural activity in stellar nerves, mantle contractions, and 3D particle tracking velocimetry in restrained *Lolliguncula brevis* to explore the role these two axon systems play in jet hydrodynamics. Of 258 jets recorded from 3 squid, 228 were initiated by the non-giant system and 30 by the giant. Jet angle did not differ between the two systems (linear mixed effects model, $p = 0.91$), but the giant axon jet impulse magnitude was significantly greater than non-giant (linear mixed effects model, $p = 0.038$). However, the distribution of non-giant impulse magnitudes (range = 0.18 to 11.7 mN s) was much broader than that for giant values (range = 1.10 to 7.70 mN s). Thus, graded control of mantle contractions by the non-giant system matched characteristics of the resulting impulse and acted as a variable force generator. Giant system impulses appeared more quantized, reflecting the all-or-none nature of these mantle contractions. Our results suggest that diversity in hydrodynamic output at different jetting speeds is influenced by differential recruitment of the squid's two neural systems.

8-2 LI, G*; LIU, H; MULLER, U K; VOESENEK, C J; VAN LEEUWEN, J L; Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Chiba University, California State University Fresno, Wageningen University; *ligen@jamstec.go.jp*

Optimisation strategies and hydrodynamic constraints in undulatory swimming: lessons learned from larval fish

To understand how undulatory swimmers maximize performance, scientists developed different measures of efficiency: Propulsive efficiency and cost of transport. To identify which measure best predicts the optimization strategy in fish, we combined experimental and computational approaches. We recorded 3D kinematics of swimming fish larvae, and used an integrated 3D computational approach that couples the Navier-Stokes equations to the motion equations describing a free-swimming fish. This combination of approaches can build parameter space maps to identify performance optima using counterfactual kinematics. We explored how body wave frequency and amplitude affect swimming performance in larval zebrafish. Our results indicate that larval fish adjust body kinematics to minimize cost of transport, rather than to maximize propulsive efficiency. To achieve this, they mainly vary body wave frequency rather than amplitude to modulate swimming speed. The strong correlation between frequency and swimming speed in undulatory fish is very likely an effect of kinematic optimization. Our computational model also predicts a negative power relationship between Reynolds number and Strouhal number, consistent with experimental observations. At a particular speed, different combinations of body wave frequency and amplitude can only cause limited variation between Re and St, suggesting that the correlation between Re and St was primarily resulted from fluid dynamic constraints. The variation further reduced as the optimum cost of transport was achieved. Our findings shed light on fundamental hydrodynamic mechanisms in fish development and behavior, and inform bio-inspired engineering designs.

10-4 LIAO, JC*; DAVE, S; ADORISIO, M; University of Florida/ Whitney Laboratory for Marine Bioscience, National Center for Biological Sciences, Bangalore, INDIA, SISSA, Trieste, ITALY; *jliao@whitney.ufl.edu*

Sensory Conflict for Fish Swimming in Flow; the Role of Vision in Station Holding

In order to maintain position and speed during navigation in current-swept environments, fishes rely on feedback from their visual and mechanosensory modalities. Using adult wild-type zebrafish, we developed a system to project high contrast visual stimuli (moving vertical and horizontal bars) onto the lateral surface of a 5 liter flow tank. Zebrafish exhibited a robust behavior of holding station (minimal drift in the downstream direction) in flows less than 20 cm s^{-1}. We discovered a robust movement response to vertical bars moving upstream and downstream when fish were challenged to swim against water flow. In contrast, fish were unresponsive to the same visual stimuli when not in the presence of water flow. Moving vertical bars elicited a more robust response than horizontal bars moving left-to-right to simulate roll. We performed separate stimulus experiments (vertical and horizontal bars, both with and without flow, and with individual fish as well as in groups of 3-5 individuals), and recorded multiple trials across several individuals.

52-4 LIEBL, AL*; RUSSELL, AF; SCHREY, AW; University of South Dakota, University of Exeter, Georgia Southern University; *Andrea.Liebl@usd.edu*

DNA methylation patterns of dispersal in a cooperatively breeding species

In cooperatively breeding societies, non-breeding individuals help rear offspring (e.g. provisioning), however variation in helping behavior exists among individuals. One hypothesis to explain this variation, kin selection, indicates that individuals are more likely to help when they are more closely related to the brood (e.g. full siblings). Thus, an important mechanism to generate helpers is for offspring of one breeding attempt to remain with their natal group and help rear subsequent breeding attempts of their parents. Therefore, whether an individual disperses or remains natal likely has significant ramifications on the fitness of that group and may have implications regarding the evolution of cooperative breeding in general. Here, using the cooperatively breeding chestnut crowned babbler (*Pomatostomus ruficeps*), we compared DNA methylation of hatchlings that remained natal following development (n= 6) and those that ultimately dispersed following development (n= 3). We used epiRADseq to generate 148,881 unique fragments. A principle components analysis of these fragments showed that DNA methylation patterns differ between reproductive strategies (i.e. dispersing or remaining natal). These results indicate that although DNA methylation is variable among individuals, clear patterns emerge consistent with behavioral strategies. Further, DNA methylation patterns at hatching are predictive of future behavioral traits.

P1-92 LIEFFRIG, SA; DERRICKSON, EM*; Loyola University Maryland; *ederrickson@loyola.edu*

The Influence of Dietary Protein:Carbohydrate Ratios on Body Composition in Two Species of Growing Mice

Researchers have shown that organisms choose a diet that preferences protein intake and that a misaligned protein:carbohydrate (N:C) ratio impacts body composition. We tested this hypothesis in juvenile mice in studies of *Mus musculus* and *Peromyscus californicus*. Reproductive females and their pups were fed isocaloric diets varying in N:C ratio. *M. musculus* pups were sacrificed at peak lactation (day 16) and *P. californicus* pups were sacrificed from peak lactation (day 20) through 85 days of age. Lean mass (primarily protein) was determined as total mass minus water, fat and ash mass. We predicted that pups on a low N:C diet would have lower lean body mass and greater fat mass. *M. musculus* pups at peak lactation on the low N:C diet had a lower total body mass and greater proportion of fat; contrary to predictions, lean mass was not different across treatments. *P. californicus* pups also exhibited slower growth as N:C ratio decreased and no difference in lean mass. However, in *P. californicus* pups, total fat was not different at 20 days and subsequently diverged between treatments with mice on the high N:C diet depositing greater amounts of fat. These results are generally consistent with the protein leveraging hypothesis. Growth rate is constrained by dietary protein and, for Mus, insufficient dietary protein results in increased fat deposition. Contrary to expectations, *P. californicus* on high N:C diets deposited fat at a higher rate suggesting that post-weaning juvenile mice may be hyperphagic beyond the need for leveraging protein.

120-7 LIGOCKI, IY*; MUNSON, A; FARRAR, V; VIERNES, RV; SIH, A; CONNON, RE; CALISI, RM; University of California, Davis; *ligocki.3@osu.edu*

The behavioral and transcriptional impacts of bifenthrin exposure in a widely introduced model fish.

In recent decades, pyrethroid pesticides have been deemed a safer alternative to previously used pesticides. While some evidence supports this in mammals and birds, exposure to certain pyrethroids can have nonlethal effects such as affecting concentrations of hormones vital to reproduction in fish. Thus, we hypothesized that pyrethroid exposure impacts fish reproductive behavior and the expression of associated genes. 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 environmentally relevant concentrations of bifenthrin and conducted behavioral assays before and after exposure. While we did not detect any changes in behavior due to exposure to bifenthrin, exposure was associated with a dose dependent increase in gene expression of estrogen receptor alpha (ER-α), while a non-monotonic response was measured in glucocorticoid receptor (GR) in brain tissue. Our study highlights the importance of using integrative approaches associated with behavior when evaluating the impact of toxicants. Merging physiological, morphological, and behavioral assessments of the nonlethal effects of pollutants will enhance our ability to predict their impact on individuals, populations, and communities.

P1-168 LIGOCKI, IY*; MILLER, J; JACKSON, L; CUMBIE, J; GIL, M; University of California, Davis, University of Florida, University of California, Santa Cruz, 1984; *ligocki.3@osu.edu*

Alone or in a group? Territory defense in solitary and group-living dusky damselfish, Stegastes adustus.

Animals that form social groups do so for a number of reasons including avoidance of predators, increased efficacy at finding or guarding food or resources, or for greater success at acquiring mates. While each of these explanations of grouping are associated with fitness gains, there are also potential costs associated with grouping depending on the size of the group, the quality of the territory, or competition in the environment. The dusky damselfish, *Stegastes adustus*, is a reef fish found in the Caribbean where it defends a territory on which it "farms" algae turf. These fish protect their territory and turf from heterospecific intruders who move through the reef and attempt to graze on the algae. Some, but not all damselfish territories are occupied by more than one fish who appear to share in territory defense and maintenance duties. We investigated variation in damselfish territory size and quality in Akumal Bay, QR, Mexico to determine i. whether larger groups hold higher quality territories, ii. whether the relative size of group member's influences territory defense, and iii. whether being a part of a group reduces the workload for dominant fish. We found that groups of fish occupied larger territories which contained more rock shelters and algal cover than solitary fish. We also found that the largest fish in groups performed the majority of territory defense behaviors. The amount of defense performed by the largest fish in groups was not significantly different from that performed by solitary fish. Taken together, these results suggest that while grouping may impart benefits on individuals in that they can maintain larger and higher quality territories, individuals do not face a reduced workload by forming a group.

P1-132 LIND, CM*; AGUGLIARO, JA; MOORE, IT; VERNASCO, BJ; FARRELL, TM; Stockton University, Fairleigh Dickinson University, Virginia Tech, Virginia Tech, Stetson University; *craig.lind@stockton.edu*

Integrating Metabolic Costs of Infection with Endocrine Indicators of Current Reproductive Investment in Pygmy Rattlesnakes Afflicted with Snake Fungal Disease

Fungal diseases have emerged as a major conservation concern in recent years. The energetic cost of coping with fungal infections competes seasonally with allocation towards life-history functions directly related to reproductive success. Such trade-offs could be reflected in circulating levels of hormones that mediate energy mobilization and reproduction in males and females. Establishing such relationships can be valuable both in terms of elucidating disease impacts and in establishing the significance of circulating hormones in conservation and management. We used a population of pygmy rattlesnakes afflicted with snake fungal disease (SFD) to examine energetic trade-offs and their endocrine basis. Specifically, we used flow-through respirometry to establish the metabolic cost of coping with SFD. We also monitored seasonal corticosterone, testosterone (males), and estradiol (females) in relation to infection status over the course of two years. Infected snakes had significantly elevated resting metabolic rates compared to uninfected snakes. Additionally, infected snakes had elevated corticosterone and lower testosterone and estradiol compared to uninfected snakes. Relationships between infection and reproductive hormones were only apparent during seasonal periods of significant reproductive investment in males and females. Results are consistent with the hypothesis that coping costs associated with SFD force allocation of resources away from processes directly related to current reproductive success and that trade-offs are mediated by adrenal and gonadal steroids.

P1-5 LINDSAY, SM*; BORGER, EC; University of Maine, Orono; *slindsay@maine.edu*

Developing Scientist Spotlights to Help Marine Science Undergraduates Build Metacognitive Skills and Science Identity

Students who can see themselves in a particular role (i.e., as a scientist) and feel that they belong to a scientific community tend to have greater academic success in STEM disciplines. Thus, how we portray scientists in our classes and textbooks, and the people that students encounter as role models and mentors matter. Students also succeed when they learn to practice metacognitive skills that faculty often take for granted. In this project, we used publicly available data to investigate the diversity of faculty in marine science/marine biology undergraduate programs at eleven institutions in the United States, comparing that to the diversity of undergraduates who completed B.S. degrees in marine science-related majors at the same institutions from 2013-2016. Not surprisingly, we found mismatches between the diversity of students and faculty in these undergraduate programs, including our own. Informed by these mismatches, we began creating "Scientist Spotlight" activities to highlight non-stereotypical marine scientists whose research coincides with key concepts taught in an introductory marine biology course. We modeled our approach on similar activities that have improved student sense of belonging in community college biology programs. In our adaptation of these activities, students reflect on the content of interviews with the spotlight scientists and associated science readings (i.e., metacognitive skills practice), and on the types of people who are scientists. Our pilot results suggest the Scientist Spotlights can provide insight about student understanding of the topic (e.g., bacterial influence on animal development), reinforce students' desire to learn more, and that students took away positive, yet realistic views of the qualities that define people who do science.

P2-215 LINDSEY, LN*; DELISLE, AL; INGLE, DN; PORTER, ME; Florida Atlantic University; *llindsey2016@fau.edu*

Cetacean vertebral trabecular bone mechanical properties vary among swimming modes and diving behaviors

Among cetaceans, species with rigid, torpedo-shaped bodies anterior to the caudal region are considered the most active, high-speed swimmers. Interspecific variation is encoded in the axial skeleton, where vertebral morphology varies among species with different modes of locomotion. Here, we categorized ten species of cetaceans based on functional groups determined by swimming modes (rigid-body vs. undulatory) and diving behavior (shallow vs. deep). The goal of this study was to determine trabecular bone mechanical properties among cetacean functional groups and regions of the vertebral column. We hypothesized that the greatest mechanical properties would be in shallow-dwelling, rigid-bodied swimmers and in the caudal regions of the vertebral column. Dephinid and kogid vertebrae were obtained from necropsies and stored fresh and frozen before testing. Vertebrae were dissected from four regions of the vertebral column (thoracic, lumbar, and two caudal) and were cut into 6 mm3 cubes. Bone cubes were compression tested in the rostro-caudal orientation at 2mm/min using an Instron E1000 material tester. Stiffness, yield strength, and toughness were calculated from stress-strain curves. Preliminary data suggest that rigid-bodied, shallow-diving cetaceans had the greatest material properties compared to undulatory, deep-diving animals, while animals with rigid bodies but habitually dive to deep depths were intermediate between the two. These data may indicate that in addition to whole body rigidity, animals that habitually overcome surface drag and wave turbulence have increased skeletal loading during active swimming than those that incorporate prolonged glides during deep dives.

108-6 LIPSHUTZ, SE*; ROSVALL, KA; Indiana University; *sara.lipshutz@gmail.com*

Endocrine mechanisms of aggression in a sex-role reversed species

Across vertebrates, testosterone (T) is considered a key player in the hormonal regulation of territorial aggression. While aggression is widespread in both males and females, endocrine regulation of aggression may be divergent between the sexes. In particular, empirical and theoretical research suggests that high levels of circulating T may not explain behavioral variation in female aggression, potentially because high T can interfere with maternal care. For species in which males conduct parental care and females aggressively defend territories (i.e. sex-role reversed), these constraints may not be as relevant, but empirical tests comparing T and aggression within and between sexes in sex-role reversed species are rare. We examined this question in sex-role reversed male and female Northern Jacanas (*Jacana spinosa*) in Panama. We simulated territorial intrusion to measure aggression and are currently measuring circulating T levels in both sexes. Results will speak to the generality of the hypothesis that T levels are constrained by parental care, lending insight into the similarities and differences in endocrine mechanisms of aggression in males and females.

P2-126 LITTLER, A.S.*; SRIRAM, A; GARCIA, M.J.; TEETS, N.M.; University of Kentucky; *asli226@uky.edu*

Out in the Cold: Genetic Correlation of Cold Tolerance Traits in Drosophila Melanogaster

Cold stress can cause a number of injuries which can lead to reduced fecundity and survival. Thus, cold tolerance is tightly linked to overall fitness and ultimately is a target for selection. Further, the extent to which selection can act on cold tolerance is dictated by the degree of heritable genetic variation. In this experiment, we examined variance in cold tolerance among isogenic lines of *Drosophila melanogaster* to test the hypothesis that commonly used cold tolerance metrics are genetically correlated. We selected 12 isogenic lineages from the *Drosophila* Genetic Reference Panel with previously known variance in lower lethal temperature. For each line we analyzed acute cold shock survival (-2°C for 1 h), tolerance of chronic cold (4°C for 24h), critical thermal minimum (CTmin), chill coma recovery (CCR), and behavioral deficits in climbing performance after cold exposure (4°C for 8h). We observed significant genetic variation for every cold tolerance measure but surprisingly found that cold tolerance measures were not significantly correlated across lines. For example, some lines had high survival after cold shock but exhibited poor CCR time, while others showed the opposite pattern. Our results demonstrate that cold tolerance exhibits significant genotypic variance, but that different metrics of cold tolerance may have distinct underlying mechanisms. Ultimately, understanding patterns of phenotypic variance across various cold tolerance traits is essential for predicting adaptation to changing environmental conditions, including those brought on by climate change.

92-1 LIU, Y*; ROLL, J; VAN KOOTEN, S; DENG, X; Purdue University Northwest, Purdue University; *liu739@pnw.edu*

Schlieren photography to study the flow around flying insects

The aerodynamic force on flying insects result from the vortical flow structures that vary both spatially and temporally throughout flight. Due to these complexities and the inherent difficulties in studying flying insects in a natural setting, a complete picture of the vortical flow has been difficult to obtain experimentally. In this work, Schlieren, a widely used technique for highspeed flow visualization, was adapted to capture the vortex structures around freely flying hawkmoth (Manduca). Flow features such as leading-edge vortex, trailing-edge vortex as well as the full vortex system in the wake was visualized directly. Quantification of the flow from the Schlieren images was then obtained by applying a physics-based optical flow method, extending the potential applications of the method to further studies of flying insects.

112-1 LIU, TX*; CHAN, KYK; Division of Life Science, Hong Kong University of Science and Technology; *tliuat@connect.ust.hk*

Interactive effects of temperature and salinity on early development of Polychaete Hydroides dirampha

In the subtropical coastal system of Hong Kong, salinity fluctuates dramatically (15.5 to 34 psu) during monsoon season and this fluctuation coincides with relatively high surface water temperature (~ 28°C) in summer. Their interactive effect was attributed to help curb the development and recruitment of the fouling tube worms based on laboratory based observations of *Hydroides elegans*. However, our field observations suggested that *H. dirampha* persisted during the summer months, and thus, we hypothesize that their early development may be less sensitive to the interactive stressor. We quantified larval survival, growth, clearance rate and settlement rate *H. dirampha* in a 2x3 factorial experiment (24 & 28°C; 20, 26, 32psu). Regardless of temperature, *H. dirampha* develops much slower or even fails to cleave under low salinity of 20. Under higher temperature (28°C), both embryo and larvae grow faster, but larval mortality increases. The larval growth, clearance and settlement rate of *H. dirampha* are significantly higher under medium salinity of 26. In contrast, the growth and settlement of sympatric congener *H. elegans* is negatively affected at the same salinity level. This work clearly illustrates how difference in larval physiological tolerance could shape abundances and distribution of a single species as well as community structure.

P1-69 LIU, J; SUNY University at Buffalo; *liujuan@buffalo.edu*
Weberian Apparatus Evolution in Fossil and Living Catostomids (Teleost, Cypriniformes)
Weberian apparatus is an evolutionary functional novelty consisting of a series of modified peri-vertebral elements for sound transmission (specialized hearing) in all Otophysi fishes. It is especially well developed in cypriniforms including members of the family Catostomidae. Complementing a rich history of anatomical study into this group, morphology of the Weberian apparatus has recently become available for study in the earliest members of Catostomidae. To explore possible evolutionary trends for this group of fish, I examined the Weberian apparatus in all the oldest catostomids (Eocene in age) and the majority of extant catostomids. The fossil taxa with preserved Weberian apparatus examined for this study include Amyzon aggregatum, A. gosiutense, A. hunanese, A. kinshenehnicum, "Amyzon" brevipinne, and Plesiomyxocyprinus arratiae. The shape and size of Weberian ossicles are similar across phylogeny and geologic ages of catosotmids, whereas other associated elements are highly diversified. Synapomorphies observed from both fossil and extant taxa are: presence of a large transverse plate between the left and right rib 4; rib 2 being fused into rib 4 and together contributing to the transvers plate; and the os suspensorium emerging from rib 4 instead of the centrum. Evolutionary trajectories across Eocene to present materials were most prominent in the length, width, and projecting direction of rib 4, the size of neural spine 4, and shape and size of the neural complex. These trends coincide with taxonomical diversification and geographical dispersal of catostomids, suggesting that Weberian apparatus evolution is associated with both speciation and niche differentiation of catostomids.

36-8 LIWANAG, HEM*; PEARSON, LE; WEITZNER, EL; VOISINET, M; WHORISKEY, S; HARRIS, HS; TOMANEK, L; JOHNSON, S; Cal Poly San Luis Obispo, The Marine Mammal Center; *hliwanag@calpoly.edu*
Development of Thermoregulatory Capability in Weddell Seal Pups
Weddell seals (*Leptonychotes weddellii*), the southernmost breeding mammals, are born into one of the most challenging thermal environments on the planet. During dependence, pups must survive on ice and in water and concurrently shift from the use of fur to a reliance on blubber for insulation. We examined the thermal and energetic costs associated with development and thermoregulation in Weddell seal pups. Mass-specific metabolic rate (MR) in air was measured longitudinally for 10 pups every 2w, starting at 1w of age through the transition to independence (7w); MR in water was measured in the same pups starting at 3w. We assessed molt status (amount of lanugo) and estimated body composition (blubber vs. lean mass) using an elliptical cones model. There was a high degree of individual variability in MR in air for 1w old pups, but it tended to decrease slightly from 1-7w of age. MR in water declined from 3w to 7w for some pups and remained stable for others. By 5w the difference between MR in air and in water was marginal for all pups. Timing and duration of the molt were highly variable among individuals. All pups gained mass from 1-5w of age (2.02 ± 0.09 kg day-1) and blubber proportion increased from 1-3w (25%-38% of body mass). Blubber proportion remained steady from 3-5w (38%-40% of body mass) because pups gained proportionally more lean mass (61% of total mass gained). Timing of MR equivalence in air and water did not vary with estimated body composition, but it did correlate with molt status. These results indicate Weddell seal pups have developed thermal capabilities by ~5w of age to combat increased heat loss in water, independent of body composition.

P3-113 LLEWELLYN, HJ*; SMITH, EN; SURMACZ, CA; HRANITZ, JM; Bloomsburg University; *csurmacz@bloomu.edu*
Sublethal Effects of the Neonicotinoid Imidacloprid on Cellular Stress in the Honey Bee Brain
Global declines in honey bees (*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 examined the effects of sublethal doses of the neonicotinoid imidacloprid on biomarkers for cellular stress, Heat Shock Protein 70 (HSP 70) and the oxidative enzyme superoxide dismutase (SOD). Honey bee foragers collected from central PA apiaries were harnessed, fed to satiation, and randomly assigned to control or imidacloprid treatments. Control bees were fed 1.5 M sucrose. Bees in treatment groups were fed 1.5 M sucrose with imidacloprid (Macho® 4.0, AgriStar) at doses of $1/5^{th}$, $1/10^{th}$, $1/20^{th}$, $1/50^{th}$, $1/100^{th}$ and $1/500^{th}$ of the LD_{50} (18 ng/bee). After four hours, bee heads were removed, frozen and homogenized. Bees exposed to high doses (1/5 and 1/10 of the LD_{50}) of imidacloprid had higher SOD activity than low doses (≤0.18 ng/bee). HSP70 levels displayed a hormetic stress response. Positive controls had higher levels of HSP70 than negative controls. The 1/100 and 1/5 treatments were lower than the positive control. Doses of 1/10 and 1/50 showed intermediate stress levels, overlapping both positive and negative controls, with $1/20^{th}$ of the LD_{50} being the median high dose. Future work will examine the effects of imidacloprid on gene expression in honey bee brains following the administration of a conservative dose of $1/20^{th}$ of the LD_{50} of imidacloprod. This research seeks to further our understanding of how neonicotinoids affect the honey bee brain and the role they may play in CCD.

P1-202 LOBERT, GT*; COLLINS, EE; MAHON, AR; Central Michigan University; *lober1gt@cmich.edu*
Phylogeography and biodiversity of Pycnogonida in the Western Antarctic
Sea spiders (Pycnogonida, Chelicerata) form a basal clade within the phylum Arthropoda that includes over 1300 species to date, with over 260 described from the Southern Ocean. Of the 264 species in the Antarctic, 108 are noted to be endemic to the region. Previous studies in the literature have found that Antarctic biodiversity is underrepresented due to sampling logistics and lack of research collections from many regions of the Southern Ocean. Additionally, sea spider identification based on morphology alone is in many cases unreliable and many cryptic species lineages have been discovered. This study aims to add to the current inventory of Antarctic sea spiders through the use of molecular barcode data and includes samples collected from throughout the Western Antarctic (Antarctic Peninsula, the Amundson, Bellingshausen and Ross Seas). With the molecular barcodes generated by this study, we will also covariate data for specimens collected to add to the biological knowledge of our species in question (location, depth, and habitat types where available). This study will increase the knowledge of Antarctic sea spiders, including cryptic species and it will improve our overall understanding of Southern Ocean faunal biodiversity and evolutionary relationships

23-4 LOCHAB, AK*; EXTAVOUR, CG; Harvard University; *alochab@g.harvard.edu*

Investigating the Molecular Basis of PGC Specification and Migration in a Hemipteran Insect

For mature gametes to form, the first precursors of the sex cell lineage must be specified and correctly localized during embryonic development. These precursors are known as Primordial Germ Cells (PGCs). Among insects, the molecular basis of PGC specification and migration has been well-characterized largely in *Drosophila melanogaster*. However, *Drosophila* germ cells (pole cells) are formed by a derived mechanism which relies on the inheritance of a maternally localized cytoplasm (germ plasm) at the egg posterior. This mechanism is not thought to be a representative mechanism of PGC specification among insects. To understand the putative ancestral mechanism for specifying PGCs, we must pursue functional genetic studies in a broader sampling of taxa. To this end, we have chosen the large milkweed bug (*Oncopeltus fasciatus*), as it lies within a sister order (Hemiptera) to the holometabolous insect orders. Embryological and gene expression data suggest that *O. fasciatus* does not have a germ plasm, leading to the hypothesis that it specifies its PGCs by inductive signaling. In this insect, PGCs are first located at the posterior of the embryo proper, and appear to migrate anteriorly before localizing in abdominal segments A4-A6. It is unknown whether these cells are actively migrating during this process. The factors responsible for directing these cells are also unknown. Members of the Bone Morphogenetic Protein (BMP) pathway instruct PGCs to form in mice (*Mus musculus*) and crickets (*Gryllus bimaculatus*), and across animals, evidence indicates that this pathway is important for various aspects of reproductive development. We hypothesize that BMP signals are instructing the specification and/or the migration of the PGCs in *O. fasciatus*. Here we present our progress in using RNA interference to test this hypothesis.

110-4 LOGAN, ML; Smithsonian Tropical Research Institute; *mike.logan1983@gmail.com*

Did pathogens facilitate the rise of endothermy?

The evolutionary success of endothermy is an enduring enigma. The energetic cost of maintaining a constant, high internal body temperature is so severe that endotherms must consume as much as thirty times the energy per unit time than an ectotherm of similar body size. What source, or sources, of selection could have favored such an energetically costly strategy? Several hypotheses for the evolution of endothermy have been proposed, including the "thermoregulation," "aerobic capacity," and "parental care" models. None of these models enjoy unequivocal support, and debate continues over the true cause or causes of the origin and maintenance of endothermy over evolutionary time. Here, I argue in favor of another potentially important source of selection in the evolution of endothermy. I draw on recent work demonstrating that fever enhances the performance of immune systems to increase the efficiency by which individuals can defend themselves against pathogens. Thus, fever-range temperatures represent the thermal optimum for immune function, and endotherms permanently maintain internal body temperatures very close to this optimum, essentially ‘priming' their immune systems for a rapid response to infection. Conversely, ectotherms employ behavioral fever, whereby they must move into warmer microclimates in order to increase their body temperatures during an infection. Behavioral fever is slow, has opportunity costs, and is strongly constrained in homogeneous thermal environments, all of which suggest that it is an inefficient way to mount a rapid immune response. An evolutionary arms race in an ancient ectotherm, whereby better behavioral thermoregulators were favored by increasingly virulent pathogens (and vice versa) could have led to the evolution of endothermy in the stem groups of modern mammals and birds.

49-6 LOLAVAR, A*; WYNEKEN, J; Florida Atlantic University; *alolavar@fau.edu*

Impacts of temperature and moisture on loggerhead sea turtle hatchlings in Florida

The influence of environmental factors during sea turtle egg development makes the ongoing threat of climate change particularly worrisome. The nest environment greatly influences various aspects of sea turtle hatchling biology, including developmental rate and sexual differentiation. Sea turtles are considered particularly vulnerable to increasing temperatures because they have a cooler male/warmer female TSD system. Another climate change effect that receives less attention is changes in precipitation patterns. Changes in precipitation pattern, in conjunction with incubation temperature increases will alter nest conditions. This study experimentally examined the impact of increased moisture on loggerhead (*Caretta caretta*) hatchling sex ratios and hatching success across 3 nesting seasons nests. Experimental treatments received water in addition to ambient levels while control treatments did not. Sand moisture and nest temperature were measured throughout incubation. A sample of hatchlings from each nest was collected and their sex was verified. Nest moisture (rainfall as well as nest watering) correlated with sex ratios and hatching success. All treatments in all years had strongly female-biased sex ratios but there was higher male production in 2017 likely due to a large rainfall event in the beginning of the season. The impact of watering is largely dependent on ambient conditions with nest watering having very little impact on sex ratios when ambient temperatures are too high. Understanding rainfall and nest moisture effects are key to demographics, particularly hatchling sex ratios. This information will increase our understanding of the variation in, and drivers of, natural sex ratios and provide better predictions of climate change effects on loggerhead hatchlings.

S9-6 LONG, Paul F*; DOONAN, Liam B; GACESA, Ranko; HARTIGAN, Ashlie; JAIMES-BECERRA, Adrian; MARQUES, Antonio C; OKAMURA, B; King's College London, UK, University Medical Center Groningen, The Netherlands, Natural History Museum, London, UK, Universidade de São Paulo, Brazil; *paul.long@kcl.ac.uk*

'Beyond Primary Sequence' - Relating Lifestyles to Variation in Cnidarian Venom

Animals often face conflicting demands associated with key processes that may be resolved by trade-offs and trait modification. In addition, these demands may vary over time as animals evolve new ecologies and lifestyles, employing ancestral traits in new ways. Some venomous animals may provide an example of the latter using toxins for both predation and defense. For example, shifts in the balance between being the hunter towards being the hunted and, *vice versa*, might be expected to alter venom composition. The resultant multi-purpose nature of toxin chemistry may also be reflected in the anatomical structures used to deliver venom. The same delivery apparatus that evolved for prey capture and may thus be used to inject venom to deter enemies. Nonetheless, few lines of evidence support the scenario that shifts in lifestyles can drive toxin diversification. Data generated using genomic, transcriptomic and proteomic approaches will be evaluated in order to explore changes in venom composition between endoparasitic cnidarians and the major morphological forms of free-living cnidarians (swimming medusae and sessile polyps). Critical insights into how venom composition may be adapted to cnidarian ecology will be discussed.

96-4 LONGO, AV*; FLEISCHER, RC; LIPS, KR; University of Florida, Smithsonian Insitution, University of Maryland; *ana.longo@ufl.edu*

Co-infections enhance invasive success of the salamander-killing fungus in widely distributed newts

Invasive fungal pathogens *Batrachochytrium dendrobatidis* (*Bd*) and *B. salamandrivorans* (*Bsal*) are causing mortality events and population declines in amphibians around the world. *B. salamandrivorans* has not been found in the Americas but is predicted to emerge there given the presence of competent hosts, high volume import pathways, and lack of effective biosecurity measures. Eastern newts (*Notophthalmus viridescens*) are the most abundant and widespread salamanders in United States with known susceptibility to both fungi. However, little is known about how their current *Bd* infections will interact with novel *Bsal* infections. Here, we ran a series of experiments in which we exposed newts to each fungal pathogen, combinations of both fungi, and three *Bd* isolates to: 1) determine if natural exposure to *Bd* provides protection against *Bsal*, 2) quantify the effect of co-infections in newt survival, and 3) examine if resistance responses are general to multiple lineages. We found that co-infections significantly increased mortality, despite that newts were able to clear *Bd* in less than a month. Unfortunately, exposure to *Bd* did not offer any protection against *Bsal*. Our findings will improve the estimates of decline risk for a species that could serve as a potential superspreader of *Bsal* in North America.

S3-11 LONGO, SJ; Duke University; *sjl53@duke.edu*

Pivots and power amplification: evolution and functional morphology of feeding in seahorses and their relatives

Power-amplified mechanisms (PAMs) have evolved multiple times independently across the tree of life and allow organisms to increase performance during a diverse array of fitness-related behaviors. PAMs are examples of complex morphological innovations, involving a number of structural components that must act together in harmony, often resulting in extreme performance that would be impossible with muscles alone. PAMs can therefore serve as case studies for the evolution of complex functional morphologies. For example, a power-amplified feeding mechanism has evolved at least once in Syngnathiformes, a group of fishes that includes seahorses, pipefishes, snipefish, and their relatives. Most syngnathiforms possess an elongated snout that they use in an unusual form of prey capture called pivot feeding, whereby dorsal head rotation brings the mouth close to prey. Some lineages have been shown to amplify power during head rotation, resulting in the fastest feeding strikes known in fishes (2ms). Pivot feeding and power amplification involve an array of changes to the feeding morphology compared to other fishes. For instance, modifications to the hyoid apparatus and suspensorium are important for latching during energy storage. A better understanding of the phylogenetic distribution of snout elongation, pivot feeding, power amplification, and hyoid-latching in syngnathiforms and outgroups is necessary to tease apart the morphological adaptations for each function (i.e., pivot feeding versus power amplification). Did the all these traits originate in concert, or was there a sequence of modifications? I will bring together information from the literature, micro-CT, phylogenomics, and biomechanics to describe the evolutionary history of one of the only known power-amplified systems in ray-finned fishes.

62-4 LOPES, PC; Chapman Univ.; *lopes@chapman.edu*

Why do We Feel Sick When Infected?

Sick animals frequently change their behaviors, exhibiting an array of symptoms collectively called sickness behaviors. These symptoms include increased pain sensitivity, decreased interest in social interactions, decreased food and water intake, and decreased activity. Sickness behaviors are host-induced, i.e., they are not the result of the infectious agent itself. Why would these uncomfortable symptoms have evolved? The operating hypothesis over the last 30 years has been that adopting these changes in behavior leads to increased survival of the host, which is supported by studies of behavioral fever. Recently, however, a novel hypothesis was put forward suggesting that sickness behaviors may have evolved to protect kin. By lowering direct and indirect contacts, sickness behaviors would lower the probability of transmission of a disease to group members, which in many animal societies are close relatives. We tested this "kin protection hypothesis" by combining data from a field and a laboratory experiment using wild house mice (*Mus domesticus*). In both, we induced sickness behaviors by injection of lipopolysaccharides (LPS). In the field, we used tissue samples from the entire population and genetic markers to determine pairwise relatedness for all possible dyads. By injecting animals in different social groups with LPS or control (saline) we quantified how natural variation in relatedness amongst groups and dyads affected the expression of sickness behaviors. In the lab, we manipulated relatedness by forming social groups in which certain animals had a close kin (a sister) and others hadn't. Using LPS or control injections we then tested whether having a close kin affected social interactions and visits to shared resources (food and water). Our findings do not provide support for the kin protection hypothesis, helping us better understand why sickness behaviors occur.

P2-140 LOPEZ, K.E.*; CHAVEZ-DOZAL, A.A.; YU, W.; SALAS, S.S.; RAMI, R.; NISHIGUCHI, M.K.; New Mexico State University, Laboratoire Arago; *klopezla@nmsu.edu*

"You talkin to me?" Interspecies communication fosters collaboration between closely related symbionts in the sepiolid squid-Vibrio mutualism

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*. *Vibrio* bacteria produce unique communication molecules known as acyl-homoserine lactones (AHLs) that used to modulate light via quorum sensing (QS). Since *V. logei* and *V. fischeri* differ in many of their physiological properties, we examined whether these species produce AHLs that could be "understood" by the other species, and whether the regulatory genes controlling AHL production and subsequently luminescence are genetically distinct. 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. Additionally, we swapped *luxO* between the two species to measure how luminescence is regulated, and whether it effects the type of AHL being produced in sympatry. Our results demonstrate that *luxO* is required for luminescence production, but additional secondary regulatory genes are responsible for *luxO* regulation even in a different genetic background. By understanding how different species of bacteria communicate inside an animal host will provide insight as to how symbiotic bacteria evolve cooperative mechanisms in complex beneficial associations.

100-6 LOUDON, C*; TRAN, K; KOK, C; Univ. of California, Irvine; *cloudon@uci.edu*

When Does A Bug Know That It Has Stepped On A Sticky Surface?

Insects associated with plants have had hundreds of millions of years to coevolve against plant defenses. Non-chemical (physically-based) plant defenses include both sticky exudates and non-sticky entrapping microstructures on the plant surface. Biomimetic entrapment technologies have been used as non-chemical methods of insect pest control, and vary in their effectiveness against different target pest species. For example, sticky traps are not considered particularly effective in bed bug control efforts, in part because bed bugs are reluctant to walk on these surfaces and will avoid them. In order to quantify this reluctance, individual bed bugs were placed in arenas, surrounded by a border of sticky surface or a non-sticky but entrapping surface for comparison (fresh leaves from bean plants, which are known to entrap bed bugs). We quantified how many times a bed bug would touch a surface with its tarsi and back off before taking more steps on the surface, and how many steps a bed bug would take before getting stuck on a surface. We did these assays with both a single choice for material and two-choice tests. We found that in the absence of choice, an individual bed bug would usually end up getting stuck on any of the surfaces within the 5-minute evaluation time window. We found that bed bugs given a choice, usually backed off from the sticky material, but not from the fresh bean leaves, and therefore usually got entrapped on the bean leaves regardless of which surface was encountered first. These results suggest that a non-sticky entrapment material is more likely to be effective in insect entrapment than a sticky material that generates an avoidance response from the bed bug.

114-7 LOUGH-STEVENS, M*; URNESS, M; HOBBS, A; GHIONE, C; DEAN, M; University of Southern California; *loughste@usc.edu*

Copulatory plugs potentially affect multiple stages of pregnancy

The mammalian copulatory plug, which coagulates after male ejaculation in the vaginal tract of females, is a well-studied target of sexual selection. The copulatory plug has been hypothesized to transport sperm, prevent rival male insemination., and stimulate females. Transglutaminase 4 (*TGM4*) has been shown to be an essential protein for the solidification of male ejaculate, and unlike other copulatory plug proteins does not appear to affect sperm quality or speed. The *TGM4* knockout mouse model (*Mus domesticus*) lacks a copulatory plug but does not show any obvious differences in body weight or frequency of copulation, yet they show a remarkable decrease in the number of litters sired. This system therefore allows us to directly test the significance of the copulatory plug, specifically its importance to reproductive success. In this study, I have attempted to isolate at which specific stages post-copulation female mice mated to $TGM4^{ko/ko}$ males have defective pregnancies. My results show that there is a decrease in (A) fertilization success, (B) the rate of implantation, yet no decrease in (C) offspring viability. Overall these results suggest that the copulatory plug plays a novel role in the early stages of offspring viability despite only being present for the first 24-48 hours.

44-5 LOUIS, LD*; KEAVENY, TM; BENTLEY, GE; DUDLEY, R; Univ. of California, Berkeley; *llouis@berkeley.edu*

Influence of laying an egg on bird bone

A female bird must mobilize an enormous amount of calcium over a short time to create an eggshell. To prepare for this challenge, she creates a unique mineralized tissue, medullary bone, on the inner surface of her bone cavities before laying an egg. Although many bird species create medullary bone, we know little about how it alters whole-bone morphology and mechanics. Furthermore, we know almost nothing about the extent to which medullary bone protects the skeleton during eggshell formation. To clarify the influence of medullary bone formation and egg-laying on whole-bone morphology and mechanics, we perform two experiments. First, to outline the influence of medullary bone formation, we created an artificial model of medullary bone by implanting adult male zebra finches (*Taeniopygia guttata*) with a silastic tube filled with β-estradiol, and compared them with males given an empty implant. Second, to describe the influence of egg-laying, we obtained female *T. guttata* in the process of creating an eggshell and compared them with females that were not yet laying. We collected micro-computed tomography data from the humerus to analyze bone morphology and performed finite element analyses (FEA) to determine effects on whole-bone mechanics. Initial results show that medullary bone formation increases bone volume fraction in the midshaft, resulting in a slight increase in whole-bone resistance to torsion and bending. Trabecular (spongy) bone volume fraction also increases via increases in number and thickness of trabecular struts. These results suggest that medullary bone may be protective, but we are working on FEA and results from the egg-laying females to form a full picture. A better understanding of how the avian skeleton handles forming an eggshell will teach us about the evolution of egg-laying behavior.

P2-249 LOUIS, LD*; BOWIE, RCK; DUDLEY, R; Univ. of California, Berkeley; *llouis@berkeley.edu*

Skeletal morphology of migratory and resident Dark-Eyed Juncos (Junco hyemalis)

Migratory birds dramatically increase the size of flight muscles in preparation for migration. However, we know very little about how migratory behavior influences bone morphology, even though bone and muscle are known to experience both mechanical and endocrine crosstalk. To determine the effects of migratory behavior on skeletal morphology and biomechanics, we analyzed specimens of both migratory and resident Dark-Eyed Juncos (*Junco hyemalis*) collected during breeding season. We obtained micro-computed tomography scans of the humeri and femora to separate the influence of mechanics (higher number of loads per day) from that of putative systemic changes (hormonal changes impacting bone morphology in preparation for migration). Our preliminary results in males show that migratory birds have a higher humerus width relative to resident birds, resulting in an increase in the ability to withstand the bending and torsional forces applied in flight. There was no difference in bone width of the femur. These results suggest that the humerus is altered to handle migration, but do not discern whether the mechanism is by increased wingbeats per day or by an increased force applied by the larger muscle. We are still performing analyses on trabecular (spongy) bone morphology and bone density. Further, analyses of an altitudinal migrant supspecies of *J. hyemalis* will enable us to tease apart the potentially confounding effects of migration and mass on bone morphology. Increasing our understanding of how migration influences bird bone morphology will clarify the evolution of morphological plasticity and migratory behavior.

P3-159 LOVE, CN*; FLYNN, RW; LANCE, SL; Univ. of Georgia, University of Georgia; *love@srel.uga.edu*
DNA Methylation Patterns in Amphibians Populations with Differing Contaminant Exposure Histories
Environmental contamination is a growing global concern, and amphibian susceptibility to contaminants varies both within and among populations. In previous work we found evidence of amphibian population adaptation to contaminated environments, however we did not explore the mechanisms and associated costs of this tolerance. DNA methylation is an epigenetic mechanism with important gene expression regulatory function in many animals and can vary with contaminant exposure. Additionally, increased global methylation patterns can contribute to accelerated aging rates and may represent a cost of contaminant exposure and/or tolerance. Our objectives were to 1) measure global DNA methylation in amphibians experimentally exposed an environmentally relevant trace element, 2) quantify variation in global DNA methylation across amphibian populations from wetlands differing trace element levels. To accomplish objective one, we exposed larvae of two species, *Anaxyrus terrestris* and *Gastrophryne carolinensis*, from populations with different exposure histories, to copper [Cu] and measured whole body global DNA methylation. *A. terrestris* larvae exhibited a negative relationship between methylation and increasing Cu exposure, regardless of exposure history. *G. carolinensis* larvae with no population history of exposure exhibited a similar pattern. However, larvae from contaminant exposed populations showed hypermethylation with Cu exposure. To accomplish objective two, we collected *Lithobates sphenosephalus* and *A. terrestris* eggs, larvae, and adults from wetlands differing in contamination type and level, and measured global DNA methylation in whole embryos, liver and brain. Broadly, DNA methylation levels increased with age, and patterns differed among species, tissue type, and wetland contamination history.

62-3 LOVE, AC*; DURANT, SE; Oklahoma State University, University of Arkansas; *ashley.c.love@okstate.edu*
Does prior infection shape reproductive investment and parental effects in birds?
Infectious diseases can have both short- and long-term behavioral and physiological effects on hosts, even after the infection has cleared. Thus, diseases experienced before breeding could have lasting impacts on parental reproductive behavior and physiology that ultimately shape the developmental environment of offspring. In this study, we quantified the effects of an infection cleared prior to mating on parental care behaviors of females and characteristics of their eggs (e.g., egg mass, yolk mass, and yolk constituents) important to hatching success and hatchling phenotype. In female canaries previously-infected with the bacterial pathogen *Mycoplasma gallisepticum*, stronger responses to infection appear to be associated with increased investment in parental care behaviors, suggesting that the severity of symptoms experienced during a recent infection could drive investment in the subsequent breeding attempt. Further, investment in eggs was influenced by *Mycoplasma gallisepticum* exposure history. This research will increase our understanding of the latent effects of infectious disease on parental reproductive investment and its ability to shape offspring phenotype through shifts in parental traits that establish the developmental environment.

P2-135 LOWDER, KB*; TAYLOR, JRA; Scripps Institution of Oceanography, UC San Diego; *kblowder@ucsd.edu*
The fountain of youth is chilly: California spiny lobster larvae progress faster in warmer water despite decreases in acidity
The phyllosome larvae of spiny lobsters spend months developing in the open-water environment, potentially leaving them vulnerable to the influence of decreasing pH and increasing temperature. Here, we studied the survival and growth of California spiny lobster (*Panulirus interruptus*) phyllosoma exposed to reduced pH and increased temperature conditions. We hypothesized that warmer temperature alone would accelerate the progression to later larval stages, but reduced pH and combined stressors would increase mortality and slow growth. Two hatches of California spiny lobster phyllosoma (8 replicates/treatment, 20 to 25 larvae/replicate) were exposed to ambient pH and temperature (8.04, 18.5 °C), increased temperature (8.04, 22.2 °C), reduced pH (7.66, 18.4 °C) and combined reduced pH and increased temperature (7.67, 22.4 °C) conditions for 3.5 (hatch 1) or 5 weeks (hatch 2). Larvae were checked for survival every three days, and a subset from each treatment were staged daily starting at 2.5 weeks. By 3.5 weeks of exposure, 33% of hatch 1 and 42% of hatch 2 in both increased temperature treatments reached Stage III of XI, rising to 100% at 5 weeks. In contrast, only 0-4% had reached this stage in the ambient and reduced pH treatments by 5 weeks. After 3.5 weeks, 15% of hatch 1 larvae exposed to increased temperature/reduced pH were alive, significantly more than the 2% of other treatments. At 5 weeks, there was no difference in hatch 2 survival among treatments (p=0.60). These findings indicate that there are no negative effects of early exposure to reduced pH on the growth rate and survival of larval California spiny lobsters, but increased ocean temperature speeds up larval development, potentially reducing larval duration and bolstering settlement.

32-8 LOWE, A*; PAIG-TRAN, M; California State University, Fullerton; *alowe@csu.fullerton.edu*
Corydoras julii: The Scute and Slide Defense
Corydoras julii is a small, Amazonian catfish armed with 44-48 bony scales called scutes on each side. The scutes are thin (~1 mm thickness), highly mineralized (55-60% mineralization), and do not imbricate (overlap) much with one another (~30% overlap, compared to >50% in other armored fishes). The scutes are mechanically reinforced with a superficial layer of a highly mineralized tissue called hyaloine. With such thin and rigid scutes, its armor may not be tough enough to prevent puncture. The purpose of this study was to study the mechanical properties and material composition of the *C. julii* armor. This was achieved by performing puncture tests on the scutes using an Instron 5942 equipped with an 18-gauge needle, approximately the same diameter as a red-bellied piranha (*Pygocentrus nattereri*) tooth. Puncture tests showed that posterior scutes are weaker (Young's Modulus=116 MPa and Ultimate Strength=1.06 N) than scutes located on the anterior (162 MPa, 1.35 N) or middle (144 MPa, 1.29 N) regions. Only 2% of punctures went through two scutes, showing the synergistic effects of fish armor's mechanical properties and that scale thickness affects puncture resistance. Feeding trials between *P. nattereri* and *C. julii* were performed to test whether *C. julii* armor could withstand *in vivo* bites from a predator. In feeding trials, *P. nattereri* targeted the weakest area of the armor, at the tail, and punctured through the armor after an average of 9.1 (+/- 3.5) bites. Additionally, they slide their armor into place so that there is additional reinforcement from scute imbrication and splay their pectoral spines in anticipation of an attack. The *C. julii* armor could not withstand repeated attacks from *P. nattereri*; however, it may be strong enough to withstand an initial predation event, allowing for them to escape while the predator reorients itself for another strike.

77-3 LOWER, SE*; FALLON, TR; CHANG, C; BESSHO-UEHARA, M; MARTIN, GJ; BEWICK, AJ; BEHRINGER, M; DEBAT, HJ; WONG, I; DAY, JC; SUVOROV, A; SILVA, CJ; Stanger-Hall, KF, University of Georgia; Hall, DW, University of Georgia; Schmitz, RJ, University of Georgia; Nelson, DR, University of Tennessee; Lewis, SM, Tufts University; Shigenobu, S, National Institute for Basic Biology; Bybee, SM, Brigham Young University; Larracuente, AM, University of Rochester; Oba, Y, Chubu University; Weng, J, Massachusetts Institute of Technology; Stanger-Hall, KF, University of Georgia; Hall, DW, University of Georgia; Schmitz, RJ, University of Georgia; Nelson, DR, University of Tennessee; Lewis, SM, Tufts University; Shigenobu, S, National Institute for Basic Biology; Bybee, SM, Brigham Young University; Larracuente, AM, University of Rochester; Oba, Y, Chubu University; Weng, J, Massachusetts Institute of Technology; Bucknell University, Massachusetts Institute of Technology, University of Rochester, Chubu University, Brigham Young University, University of Georgia, Arizona State University, National Institute of Agricultural Technology, University of Rochester, Centre for Ecology and Hydrology, University of California Davis; *s.lower@bucknell.edu*
Firefly genomes illuminate parallel origins of bioluminescence in beetles
Fireflies and their captivating luminous courtships have inspired centuries of scientific study. Today, firefly luciferase is widely used in biotechnology; however, the evolutionary origin of their bioluminescence remains unclear. To shed light on this long-standing question, we sequenced the genomes of two firefly species that diverged over 100 million-years-ago: the North American *Photinus pyralis and Japanese Aquatica lateralis, as well as the genome of a related luminescent click-beetle, the Caribbean Ignelater luminosus . A variety of sequencing and assembly strategies, including hybrid assembly of long PacBio and short Illumina reads and scaffolding with HiC long-range data, yielded excellent genome assemblies. Subsequent analyses support two independent gains of bioluminescence between fireflies and click-beetles, and provide new insights into the genes, chemical defenses, and symbionts that evolved alongside their luminous lifestyle.*

P2-148 LOWNDS, BI*; TOPPING, NE; JOST, JA; Bradley University ; *blownds@mail.bradley.edu*
Linking Environmental Conditions to Zebra Mussel (Dreissena polymorpha) Growth and Performance in a Central Illinois Population
The invasive zebra mussel, (*Dreissena polymorpha*), has caused significant ecological and economical damage. While their physiology has been examined for a variety of environmental conditions both in the field and the lab, there are gaps within the literature. First, little is known about the cellular processes during environmental fluctuations. Second, there are discrepancies in the reported values for both optimal and lethal temperatures, which may be attributed to localized adaptation or acclimation. However, these differences make it challenging to develop biologically relevant laboratory experiments without knowing the thermal limits for our specific population. Therefore, our objectives were to determine the optimal conditions for a zebra mussel population at Banner Marsh by linking growth (shell size, shell mass, and tissue mass) to environmental parameters (water quality, food quantity, and temperature). Field enclosures were deployed for a period of four weeks in May and again in mid-June. Within each enclosure mussels were either clumped or divided into individual chambers. On average, mussels experienced greater shell growth and lower tissue loss when they were housed individually, suggesting that clumping behavior negatively impacts growth. Also, mussels experienced greater shell growth and lower tissue loss in May than in June. While water quality and food quantity varied over time, conditions remained within optimal limits. Since temperatures regularly exceeded 31°C in June and July, the relatively poorer performance in June and July may be attributed to greater temperature stress. We are currently measuring the levels of two cellular stress markers to determine the role of cellular physiology in this response.

121-6 LOZIER, JD*; PIMSLER, ML; OYEN, KJ; JACKSON, JM; HERNDON, JD; DILLON, ME; STRANGE, JP; LOZIER, Jeff; University of Alabama, University of Wyoming, Utah State University, University of Wyoming; *jlozier@ua.edu*
Biogeography and functional genetics of thermal tolerance across latitude and elevation in a widespread bumble bee
A central question in evolutionary biology is: by what mechanisms do organisms adjust to abiotic variation across their geographic range? While individuals can tolerate a wide range of variation, do they use the same mechanisms at different abiotic extremes, and do populations across a species range employ the same strategies or exhibit local adaptation? Bumble bees often have large geographic distributions that include both latitudinal and altitudinal variation and are thus excellent models to study evolutionary responses to spatio-environmental gradients, especially temperature. Using laboratory-reared *Bombus vosnesenskii* from low and high elevation sites at northern and southern extremes in California and Oregon, we quantified critical thermal limits and differential gene expression to test for population-specific differences relating to conditions across elevation and/or latitude. Gene expression was measured using RNA sequencing. Critical thermal limits were correlated with climate conditions of queen collection locations. Gene expression also exhibited strong population-specific effects in magnitude, identity, and quantity of differentially expressed genes. We examine results in parallel with a large-scale SNP-based population genomic study of local adaptation across the *B. vosnesenskii* range. The results have implications in the evolution of thermal adaptation, bumble bee biodiversity, and conservation in a changing climate.

86-6 LUBECK, L.A.*; GRAUMAN, B; SEITZ, T; SWALLA, B.J.; Brown University, Providence, RI, Wellesley College, MA, Friday Harbor Laboratories, University of Washington, Seattle; *lauren_lubeck@brown.edu*
Clone Alone: Lithium Chloride Induced Cloning in Dendraster excentricus
Echinoderms reproduce sexually as adults, but can reproduce asexually in the larval stage by cloning. Stressors, such as the presence and perceived presence of a predator, variations in food availability, and variations in temperature conditions have been found to cause larval cloning. Cloning may represent a way to overcome adverse conditions by generating another larva to the pelagic zone. This mechanism could allow for increased larval survival and increased chances of metamorphosis, benthic settlement, and reproduction. When a larva clones, it reproduces and increases its fitness before reaching sexual maturity in the adult stage. If cloned larvae are able to clone themselves and produce viable offspring, this would represent an increased larval population size and longer planktonic duration. This possibility represents a novel feature of the larval life stage, the potential to survive difficult environments and eventually develop into benthic adults. While cloning plays an important role in the larval life history, the molecular mechanism(s) behind it is unknown. In regeneration studies, the *wnt* pathway is known to be a key signaling molecule. We hypothesized that the *wnt* pathway also has a role in cloning. Using lithium chloride to inhibit glycogen synthase kinase 3β and activate the *wnt* pathway, we provide a reliable method to induce cloning in *Dendraster excentricus* larvae. Antibody staining of DAPI and β-catenin show β-catenin localization into the nucleus and activation of the *wnt* pathway in the larvae. Our results allow for increased laboratory research in echinoderm cloning now that clones can be produced reliably.

103-4 LUCAS, KN*; LAUDER, GV; TYTELL, ED; Harvard University, Tufts University; *kelsey.n.lucas@gmail.com*
Low and High Pressure Both Contribute to Force Production in Body-Caudal Fin Locomotion in Fishes
Fishes must swim effectively to catch prey, evade predators, and find shelter and mates. Since these behaviors are important for evolutionary fitness, understanding how mechanical forces are produced by a fish's body and appendages can provide insight into the evolution of their present body forms. Traditionally, we have assumed that thrust production occurs by body movements pushing fluid rearward, creating areas of high pressure around the body that in turn push the fish forward. Yet, areas of low pressure are created in tandem with these high-pressure locales. For lampreys, the pulling forces arising from these low-pressure regions contribute significantly to total thrust, but for other fish species, the role of such pulling forces is not known. Here, we use a particle image velocimetry-based technique to calculate the pressure distributions around bluegill sunfish (*Lepomis macrochirus*) and brook trout (*Salvelinus fontinalis*) during steady, free swimming. From these pressure data, locomotor forces can be accurately estimated at high spatial and temporal resolution. We find that high and low pressure both contribute to thrust and drag production, and they do so in different patterns along the body. We demonstrate that these low-pressure-based thrust forces are distributed along the body and are not solely localized to the caudal region, which has been suggested to be where thrust is primarily generated in carangiform swimmers. These results show that fishes may simultaneously use a variety of mechanisms to produce forces. Developing a more complete understanding of these mechanisms may ultimately help illuminate how the requirements for effective force production constrains the evolution of fish body forms.

17-2 LUGER, AM*; DUTEL, H; FAGAN, M; HERREL, A; DE KEGEL, B; ADRIAENS, D; Ghent University, University of Hull, M.N.H.N.; *allison.luger@ugent.be*
Understanding the role of the musculature in the prehensile tail of chameleons
Prehensile appendages represent an adaptation that has evolved in various vertebrate and invertebrate lineages. Prehensility is the ability to hold and grasp firmly onto an object, combining flexibility and strength. Chameleons (Chamaeleonidae) typically have an arboreal lifestyle and use their prehensile tails for anchoring and as a support during feeding. By linking the variation in morphology and musculature to function, we aim to explain what it takes to make a tail prehensile. A previous study focused on the morphological variation in tail vertebrae of prehensile and non-prehensile chameleon species using µCT data, however without information on tail musculature this data alone does not allow functional testing and analysis. Our morphological data showed considerable shape variation in the transversal spine between prehensile and non-prehensile species. For this study, we focus on the muscle bundles that attach to the transversal spine, in particular the m. ilio-caudalis, which has an important role in the torsion and ventral flexion of the tail. Both length and angle of the transversal spine differ between prehensile and non-prehensile species, as well as regionally within the tail. Prehensile species have a longer transversal spine pointing distally, that decreases towards the distal end. Studying prehensile function at a musculoskeletal level, we used µCT scans of PMA stained specimens and dissections to reveal where on the spine the muscles attach and how many vertebrae they cross before insertion. Using that muscle data as input with a virtual 3D reconstructions of the tail vertebrae, we used multibody dynamics analysis to investigate the role of the individual muscles on the movement and function of the tail.

P1-54 LUNA, M*; AMTHOR, A; YAEGER, J; NOEL, A; NADLER, N; Georgia Institute of Technology, Georgia Tech Research Institute; *mluna7@gatech.edu*
Bio-Inspired Fluid Transport of Spanish Moss
The Spanish moss (Tillandsia Usneoides) is an epiphytic, bromeliad that uptakes water and fog from the atmosphere. The outer epidermis surface of the Tillandsia is coated with wing-shaped trichomes that when wet bend downwards, creating a superhydrophilic film of water between the epidermis and the trichome that flows in a single direction. In this study, the Tillandsia Usneoides trichome wing structure was investigated for biologically inspired fluid transport applications. We also preformed relative humidity experiments of the Tillandsia with and without trichomes. These experiments demonstrated that Tillandsia with removed trichomes increased relative humidity 22.7% more than that of the intact Tillandsia. The Tillandsia's trichomes also conserve 19.7% more of its total mass within a 24-hour period, suggesting increased water retention for Tillandsia with trichomes. Through bio-inspiration from the Tillandsia Usneoides' unique trichome structure, a bio-mimicking mechanism using hydrogels is suggested. Biomimicry of the Tillandsia can be valuable for applications requiring fluid spreading and retention, such as systems that require constant lubrication.

67-1 LUND, R.*; GROGAN, E. D.; JACOB, A.; St Josephs University, Philadelphia; *egrogan@sju.edu*
A 320 million year old rayfin fish ahead of its time - A radically different skeletal design in the Paleozoic
The actinopterygian fish nicknamed "Aphol" was a relatively common member of the Serpukhovian (Upper Mississippian) marine Bear Gulch community. The body is scaleless, low and elongate. The head is extremely narrow anteriorly and devoid of any solidly sutured or abutting bones except two paired dorsal elements. The mouth is terminal. Eye orbits are large and far forward. In all well-preserved specimens there is a flexure of the body in the mid-abdominal region. Pectoral fins are positioned vertically upright orthogonal to the body long axis. Pelvic fins are absent. A low dorsal fin extends from the fourth vertebra to the tail. A discrete anal fin is lacking but a continuous row of infrahemals extends from the first hemal arch to the beginning of the caudal fin. The tail is small, externally pointed and internally hemiheterocercal. The vertebral column is highly regionalized and strikingly specialized compared to the prevailing actinopterygian design of this age. A very flexible cervical and anterior abdominal vertebral span is followed by vertebrae with median neur- and hem-apophyses as well as pre- and post-zygaphophyses. These would render the posterior abdominal and caudal regions virtually rigid. The caudal vertebral elements and fin form a specialized complex. These characters converge upon diverse teleosts from heterocongrin and ophichthid eels to symbranchiids to thunniform swimmers. It is tantalizing to consider the life style of this enigmatic fish.

10-2 LUNSFORD, ET*; SKANDALIS, D; LIAO, JC; Whitney Laboratory for Marine Biosciences, University of Florida; *elunsford@ufl.edu*

Efferent Neurons have Binary Control over the Lateral Line during Swimming

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 hydrodynamic cues in their fluid environment. This is possible because the deflection of mechanosensory neuromasts by fluid motion results in an increased frequency of action potentials in the afferent neurons. Afferent neurons are also spontaneously active which has been shown to maintain sensitivity and frequency discrimination. During swimming self-generated fluid motion stimulates the lateral line, and efferent neurons in the hindbrain send a corollary discharge of the motor command to modulate action potential activity by controlling hair cell transmitter release. By simultaneously recording from afferent neurons and ventral motor roots using extracellular recordings in 4-6 day post fertilization larval zebrafish (*Danio rerio*), we discovered that the spontaneous frequency of afferent action potentials decreased during fictive swimming. For more than 280 swim events across 34 individuals, we found that afferent spontaneous activity was completely inhibited during 62% of swim events. Higher spontaneous spike rates were correlated to a lower likelihood of afferent inhibition. To quantify the functional contribution of cholinergic efferent neurons, we selectively labeled and then ablated their hindbrain soma with ultraviolet light. Electrophysiological recordings revealed that the likelihood of afferent inhibition was reduced by approximately 50% after ablation. This study indicates that the lateral line system is less sensitive during locomotion and suggests that the cholinergic efferent system works to limit sensory feedback.

86-1 LUTTRELL, SM; SU, Y-H; SWALLA, BJ*; Univ of Washington, Seattle, Academia Sinica, Taiwan; *bjswalla@u.washington.edu*

Getting a Head with Hemichordate Larval Regeneration

Severe injury to the central nervous system (CNS) of chordates often results in permanent and irreversible mental and physical challenges. While some chordates are able to repair and/or regenerate portions of their nervous system, no chordate has been shown to be able to regenerate all regions of their CNS after catastrophic injury or amputation. Some hemichordates, on the other hand, are able to efficiently regenerate all neural structures, including their dorsal, hollow neural tube after complete ablation. Hemichordates are marine acorn worms and a sister group to the echinoderms. The hemichordate, *Ptychodera flava*, develops from a pelagic, feeding tornaria larva to a tripartite, benthic worm with an anterior proboscis, a middle collar region, and a long posterior trunk. The adult worm regenerates all body parts when bisected in the trunk, but it was unknown whether the regeneration program was present in tornaria larvae. We have shown that *P. flava* larvae are capable of robust regeneration after bisection through the sagittal, coronal, and axial planes. We used immunofluorescence to show that the apical sensory organ regenerates a rich, serotonin positive complex of cells within two weeks after amputation. Cells labeled with EdU (5-ethynyl-2'-deoxyuridine) confirm that regeneration is occurring through epimorphic processes as new cells are added at the cut site and throughout the regenerating tissue. This study verifies that *P. flava larvae* can be used for future functional studies aimed at identifying the genetic and morphological mechanisms controlling CNS regeneration in a stem deuterostome. Biol. Bull. (2018) 234: 152-164.

14-3 LYNCH, KS*; O'CONNELL, L; BALAKRISHNAN, C; MCKIM LOUDER, M; FISCHER, E; Hofstra University, Stanford University, East Carolina University; *kathleen.lynch@hofstra.edu*

Understanding the genetic and neural basis of avian brood parasitism

Animals that use an evolutionarily derived parental care strategy, rather than a strategy that is ancestral to its group, may provide unique insight into the genetic architecture of parental care. Roughly 1% of bird species are brood parasitic, which is an evolutionary derived strategy in which males and females display no parental care whatsoever. We explore this alternative parental strategy by examining the genomic basis for brood parasitism using brain region-specific transcriptome comparisons. Using comparative transcriptomic approaches, we identified gene expression patterns specifically within the preoptic area (POA), a brain region that plays a critical role in the regulation of maternal care. We compared POA transcript patterns in parasitic brown-headed (Molothrus ater) and bronzed cowbirds (M. aeneus) in relation to juvenile and adult red-winged blackbirds (Agelaius phoeniceus), a closely related non-parasitic species. We evaluated three alternative explanations for the evolution of brood parasitism: reduced expression of parental care-related genes in the POA, increased expression of genes inhibiting parental care, and retention of juvenile-like (neotenic) gene expression. We did not find evidence for large scale gene downregulation in brood parasites. Expression patterns did reflect substantial evidence for neotenic POA gene expression in parasitic birds. Differentially expressed genes with previously established roles in parental care were identified as well as genes that may inhibit parental care. These results provide a foundation to further examine whether the neural- and genetic-basis underlying brood parasitism is conserved across other parasitic species.

50-4 LYNCH, LM*; HOLLEMAN, G; BOOTH, W; Washington University School of Medicine, University of Tulsa; *lynch.leigha.m@wustl.edu*

Accurate phylogenetic relationships can be produced from fragments of DNA

DNA is commonly used to hypothesize the phylogenetic relationships among species. Degraded DNA can be sourced from fossils, scat, and soil, but its fragmentary nature can result in the capture of only partial gene sequences. It remains to be determined, however, whether the relationships hypothesized from partial sequences are equivalent to those from complete genes. Using complete sequences of cytochrome b (cytb) and mitochondrial genomes from GenBank, we sought to determine how many base pairs of a gene are required to generate accurate phylogenetic relationships and whether this length differs across clades. We included 34 species from Alligatoridae, Dactyloidae, Plethondontidae, Bovidae, Felidae, Mustelidae, and Phosianidae. For both cytb and the mitochondrial genomes, we aligned sequences from each family independently and then cropped the sequences by 150bp from the 5' end until $\leq$ 150 base pairs (bp) remained. We chose a 150bp increment because it is a common read length in NextGen sequencing platforms. We then ran a maximum likelihood phylogeny for each subsampled sequence. To determine which phylogenies differed statistically from the topology produced by the complete gene/genome sequence we ran a Shimodaira-Hasewaga test. Per a p-value threshold of 0.05, we found that statistically equivalent tree topologies can be produced from cytb sequences >300-450bp, depending on the clade. We also found that at least 4650bp are required from the mitochondrial genomes of mammals. This is approximately one third of the genome length. The results of this study indicate that partial gene sequences provide comparable data to complete genes. This is encouraging for studies using degraded DNA, as these short sequence lengths have a higher likelihood of capture than full genes/genomes.

P2-107 LYNN, S.E.*; KERN, M.D.; The College of Wooster; *slynn@wooster.edu*

Characterizing the effects of early life cooling on HPA axis development in free-living songbirds

Early life experiences can affect the function of the hypothalamo-pituitary-adrenal (HPA) axis of vertebrates, with potential fitness consequences. We have shown that repeated drops in body temperature during the first week of life of eastern bluebird (*Sialia sialis*) chicks, such as those which occur when females are away from the nest, dampen the chick HPA response to restraint prior to fledging. To explore which aspects of the HPA axis are affected by cooling, we subjected chicks to experimental cooling during the first week of life (Cooled chicks) or maintained chicks at brooding temperatures (Controls). Prior to fledging, we characterized corticosterone (CORT) secretion after (1) 60 min of restraint (to confirm the effects of cooling on HPA activity), (2) injection with adrenocorticotropic hormone (ACTH; to assess adrenal sensitivity), or (3) a dexamethasone (DEX) suppression test (to characterize negative feedback sensitivity of the HPA axis). We confirmed that repeated cooling early in life reduced CORT secretion in response to later restraint. Sensitivity to ACTH challenge did not differ between temperature treatments, but, compared to Controls, Cooled chicks exhibited impaired negative feedback sensitivity. This unexpected result does not, however, explain our consistent finding that Cooled chicks have a lower CORT response to restraint than Controls. Our data suggest that early life cooling alters the HPA axis at multiple levels. We hypothesize that cooling also alters HPA axis function at the level of the hypothalamus or anterior pituitary. Such effects are likely to be strong, with early life cooling producing an overall dampening of CORT secretion in response to novel stressors, despite impairing negative feedback of the HPA axis to glucocorticoids.

51-7 LYONS, K*; WYNNE-EDWARDS, KE; University of Calgary; *kady.lyons@sbcglobal.net*

Embryonic Steroidogenesis in an Elasmobranch with Matrotrophic Histotrophy

Steroid hormones play a crucial role in the initiation and maintenance of pregnancy in live-bearing vertebrates. Despite the diversity of maternal provisioning strategies, little research has investigated embryonic steroidogenesis. Pregnant Round Stingrays (*Urobatis halleri*) were captured from two sites in southern California and paired samples of maternal plasma and uterine fluid (histotroph) were analyzed for a suite of 11 steroid hormones using a liquid chromatography system connected with tandem mass spectrometer equipped with electrospray ionization source. More steroids were detected (at higher concentrations) in histotroph samples compared to maternal plasma. In particular, histotroph progesterone and testosterone were highest during early gestation, coinciding with the appearance of secondary sex characteristics in embryos (i.e. presence/absence of claspers). This study is one of the first to examine steroid hormones in elasmobranch histotroph, and suggests that embryonic steroidogenesis begins early in development and is likely to influence sexual differentiation.

86-2 MACDONALD, G; SNYDER, M; GIBSON, G*; Acadia University; *glenys.gibson@acadiau.ca*

An Epigenetic Mechanism for Phenotypic Plasticity in the Annelid Polydora cornuta.

Parental environment plays a significant role in influencing offspring phenotype through epigenetic modifications. We tested two hypotheses: that methionine in the parental environment induces plasticity in offspring phenotype in the polychaete *Polydora cornuta*, and that methionine alters DNA methylation in spawning females. Methionine was tested as it is essential in the DNA methylation process and because it is considered limited in the diets of marine detritivores. Adults were cultured in seawater (controls) or at three concentrations (10^{-5}, 10^{-7}, 10^{-9}M) of methionine. Control broods had the typical pattern of developmental plasticity and produced three morphs of offspring in equal proportions (i.e., small larvae, mid-sized larvae, and large juveniles). Parental exposure to methionine altered larval phenotype with the highest exposure (10^{-5}M) increasing the production of small larvae, and the lowest exposure (10^{-9}M) producing a range of larval morphs similar to controls. Differences in maternal methylation were demonstrated through total genome digestion with methyl-sensitive isoschizomers (HpaII, MspI), generating DNA smears with gel electrophoresis, and analyzing intensity plots with Image J. Exposure of females to all three concentrations of methionine significantly reduced DNA methylation relative to the controls. These results indicate that developmental plasticity in *P. cornuta* is epigenetic and is influenced by a potentially limiting nutrient (methionine) in the parental environment.

P1-129 MACKAY, S.B.; TRAINOR, C.*; WILSON, K.; BERGMAN, D.A.; Grand Valley State University; *trainorc@mail.gvsu.edu*

Effects of Nonylphenol on Crayfish Molting Hormones

Nonylphenol (NP) is a commonly used surfactant in a variety of industries. NP shows an affinity for estrogen receptors, hence its classification as an endocrine disruptor and potential danger to reproductive success. NP accumulates in aquatic environments and several studies have demonstrated reduced olfaction and impaired gonad development and feminization in a variety of species after exposure. Previous research suggests that NP exposure can also lead to reduced molting. As molting is triggered by ecdysone release or inhibited by molt inhibiting hormone (MIH) release, this decrease in molting could be attributed to interference with either aspect of this endocrine controlled system. Increases in MIH or decreases in ecdysone are potential mechanisms for delayed or diminished molting. However, changes in the concentrations of these hormones are not the only possible site of interference as competitive receptor binding inhibition could change molting frequency. We hypothesize that NP will disrupt the molting hormone signaling pathways. To test this hypothesis, we quantified hormone concentrations in the hemolymph and receptor expression in gonad tissue during nonylphenol exposure.

120-3 MACKAY, S.B.*; TRAINOR, C.P.; WILSON, K.L.; BERGMAN, D.A.; Grand Valley State University; *mackays@mail.gvsu.edu*

Chronic Effects of an Environmental Contaminant on Reproductive Behavior and Physiology

Nonylphenol (NP) is a commonly used surfactant in a variety of industries. Nonylphenol shows an affinity for estrogen receptors, hence its classification as an endocrine disruptor and potential danger to reproductive success. Nonylphenol accumulates in aquatic environments and several studies have demonstrated reduced olfaction and impaired gonad development in a several species after exposure. Although acute studies have been performed, chronic exposure studies are limited. A total of 240 crayfish, *Orconectes propinquus*, consisting of 60 adult males, 60 adult females, 60 juvenile males, and 60 juvenile females were collected. They were then exposed to NP for four months. Repeated behavioral assays were performed using a Y-Maze and electrophysiological recordings of antennules were obtained. Individual weekly mass, molting events, mortality, and final gonad mass were all recorded during exposure. Exposing crayfish to varying sublethal concentrations of endocrine disrupting nonylphenol alters reproductive behavior through chronically hindering electrophysiology and altering developmental processes. Our data suggests that NP exposure also leads to reduced molting. We quantified hormone concentrations in the blood and receptor expression in gonad tissue during nonylphenol exposure to determine if NP will disrupt the molting hormone signaling pathways. Despite these concentrations being below current regulations, detrimental effects still exist. This necessitates the re-evaluation and implementation of an indefinite exposure, low-level guideline if nonylphenol continues to be used in a wide variety of industries.

25-3 MACKIEWICZ, AG*; PUTLAND, RL; MENSINGER, AF; University of Minnesota Duluth; *macki059@d.umn.edu*

The effect of anthropogenic noise on Oyster Toadfish (Opsanus tau) vocalizations

Over the last century, human activities, including the use of motorized watercraft, have increased the amount of noise in the aquatic environment. The masking effect of overlapping frequencies produced by motorized watercraft and the hearing range of fishes could lead to a reduction in communication ability and ultimately a failure in mate attraction and detection. For the oyster toadfish, *Opsanus tau*, vocal communication and sound detection are critical for reproductive success, yet little is known about how they respond to changes in their acoustic environment. This study used passive acoustics to monitor and determine the effect of natural anthropogenic noise, produced by boats in situ, and artificial anthropogenic noise via speaker playback trials on toadfish. A four-hydrophone linear array was deployed in Eel Pond in Woods Hole, MA, where a natural population of toadfish and numerous motorized watercraft reside. Natural anthropogenic noise decreased the amount of vocalizations compared to artificial anthropogenic noise, which had a minimal effect. The amplitude and duration of the vocalizations, and location of individual toadfish were also characterized. The effect of anthropogenic noise on aquatic life is a fundamentally important topic in ecology. This study highlights that anthropogenic noise influences the underwater environment and vocal communication of aquatic life. Moving forward, passive acoustic monitoring of key species, such as the toadfish, can help management to prioritize acoustically sensitive times and areas.

4-7 MACKNIGHT, NJ*; DIMOS, B; LASSEIGNE, D; MULLER, E; BRANDT, M; MYDLARZ, L; The University of Texas at Arlington, The University of the Virgin Islands, Mote Marine Laboratory, The University of the Virgin Islands; *nicholas.macknight@uta.edu*

Caribbean Coral Species Differ in Susceptibility and Immune Response to White Plague Disease

54% of global coral reefs have died within the last thirty years and disease outbreaks have shown to play a significant role in altering the structure of the reef community. Corals have different susceptibilities to disease and understanding how disease dynamics differ between species and the role of immunity in these patterns will give insight and allow us to make trait-based predictions of future reef populations. We measured the disease susceptibility and immunity gene expression of seven common Caribbean reef-building coral: *Colpophyllia natans*, *Montastrea cavernosa*, *Orbicella faveolata*, *Orbicella annularis*, *Porites asteroides*, *Porites porites*, and *Siderastrea siderea*. White plague disease was transmitted from infected coral to healthy coral fragments in a controlled experiment. Disease prevalence and severity differed among all species. *Orbicella faveolata* and *O. annularis* had the highest prevalence of disease, followed by *Colpophyllia natans*, and *Siderastrea siderea*. Both *Porites* species and *Montastrea* showed little to no disease phenotype. Using RNAseq the coral's immune response and network were examined. Preliminary data shows exposure to white plague disease produced a significantly different gene expression profile in *Orbicella faveolata*. Weighted Gene Correlation Network Analysis was applied to infer the relationship between gene expression profiles and white plague exposure, infection, and tissue loss and relevant modules of gene networks were identified as significantly correlated. Employing gene ontology enrichment and WGCNA will provide insight into the plasticity of the transcriptome in all seven species in relation to the diseased state.

P1-157 MACLEOD, P.F.; O'ROURKE, C.; RENN, S.C.P*; Reed College, Portland OR, Reed College Biology Department; *renns@reed.edu*

Manipulating operational sex ratio to influence female competition and male choice in a lek-like mating system.

Social living, while adaptive in terms of enhanced access to mates and predator avoidance, also comes at a cost in terms of increased competition for resources and limitation regarding an individual's opportunity to mate. As such, competition in social groups often leads to the formation of dominance hierarchies, established and maintained by agonistic interactions. These hierarchies often serve to ameliorate within-group conflict and reduce the costs of fighting conspecifics. The most frequently studies dominance hierarchies are those observed among males under conventional sex-role mating systems in which reproductive success is highly variable for males. In such situations, females are generally considered to play a passive role, selecting from dominant available males. However, potential exists for females to also compete with each other in these arenas. The cichlid fish *Astatotilapia butroni* provides an interesting opportunity to study how female competition and male choice are influenced by the operational sex-ratio. In this maternal mouth-brooding lekking species, the females remove themselves from the available breeding population while brooding young in their buccal cavity. This allows us to manipulate the operational sex-ratio while maintaining consistent encounter rates among females as well as between males and females. We find that as the number of available females per male increases, the rate of female directed aggression by females increases, consistent with an increased competition for male mates. Female directed aggression by males also increases, consistent with male choosiness when the number of available females per male increases. These data support a more nuanced interpretation of conventional sex-role theory.

97-2 MADELAIRE, CB*; ZENA, LA; BUCK, CL; BICEGO, KC; GOMES, FR; Univ. of São Paulo, Northern Arizona Univ., São Paulo State Univ.; *cmadelaire@yahoo.com.br*

Seasonal relationship between steroids and immunity in a hibernating tegu lizard

Steroid hormones are considered mediators of life history stages in vertebrates, due to their broad effect on animal physiology and behavior. For seasonal species, there is an increase in androgens (T), estradiol (E) and glucocorticoids (GC) during reproductive season, which allows and facilitates this process. These steroids also display complex immunomodulatory effects, which depends on hormonal concentration, temporal pattern and individual condition. We are investigating the seasonal covariation of steroid levels (T, E, GC), immune parameters (leukocyte profile and bacterial killing ability) and body condition index in males and females of the tegu lizards (*Salvator merianae*), a species that display pronounced transitions in life history stages along the year. We expect immunity to be positively correlated with steroids and body condition during reproductive phase, and lower immunocompetence during hibernation compared to the rest of the year. Considering the differential investments in reproduction among males and females, we also expect to found differences on immunity among sexes. The links between of season, sex, body condition index, hormone levels, and immunological parameters will be tested.

P2-117 MAENAGA, ML*; FORMICA, VA; NOVARRO, AJ; Swarthmore College; *mikamaenaga@gmail.com*

Eat or Be Eaten: Exploring the Relationship Between Stress Response and Cannibalism in Beetle Larvae

Animal survival depends on an effective and appropriate stress reaction. One immediate reaction to external stressors, such as predators and competitors, is an increased heart rate. Heart rate reactions are linked with the fight-or-flight response and may be especially important for organisms that experience frequent aggressive interactions. As larvae, forked fungus beetles (*Bolitotherus cornutus*) regularly cannibalize one another and can spend up to 3 years living on a shared, limited resource. Thus, individual stress responses may shape the outcome of extreme competitive interactions, and therefore survival. In this study, we explored the relationship between heart rate reactions and cannibalism in *B. cornutus* larvae. We hypothesized that individuals with a greater heart rate response to stress are more likely to survive cannibal interactions with competitors. To test this hypothesis, we measured the stress response of lab-reared larvae as the change in heart rate when exposed to an environmental stimulus (direct light) relative to the baseline heart rate. We then paired larvae of similar sizes in cannibalism arenas to determine which individual would cannibalize their competitor, and latency to do so. Of the 39 pairs we placed in cannibalism arenas, we observed an 85% rate of cannibalism. Given the intense rate of cannibalism, we suspect that physiological traits for evading cannibalism are under strong selection. Our experiment will allow us to determine whether individual stress response is related to survival probability in the face of extreme competition. Understanding the physiological link to aggressive behavior will contribute to the limited knowledge of stress physiology in invertebrates.

P3-2 MAGUIRE, M.C.*; HAMBELTON, G.; ELLERS, O.; DICKINSON, P.; JOHNSON, A.S.; Bowdoin College; *mmaguire@bowdoin.edu*

Contributions of artery and sarcomere length changes to the heart's ability to generate tension in the American lobster, Homarus americanus

With increased activity, the heart's blood volume during diastole increases, which consequently increases the stretch on the walls of the heart. As is typical with striated muscles, the ability of the heart to generate tension increases with increasing stretch up to some maximum. This increase in tension-generating ability may be due to sarcomeres generating greater force at longer lengths on the ascending limb of the length-tension curve. However, lobster hearts are suspended by elastic ligaments and arteries within a pericardial space, thus the tension on the heart is influenced both by changes in sarcomere length during diastole and artery stretch during systole. Furthermore, the heart is anisotropic, with characteristically different active forces along the transverse and longitudinal axes. We examine the effects of both sarcomere and artery length changes on tension generation by the heart at different points in the cardiac cycle as well as the potential contribution of differences in sarcomere length to the observed anisotropy. In terms of anisotropy, no significant differences in sarcomere length were found between longitudinal and transverse fibers. In terms of length-tension curves, we found that tension increased with increasing length of the heart plus artery system, but that the initial portion of the whole-heart length-tension curve occurred at lengths where the arteries were responsible for absorbing the imposed changes in length. Thus, whole-heart length-tension curves for lobster heart suggest potential neural stretch receptors in the arteries that anchor the heart in the pericardium.

P1-125 MAHONEY, A*; FUSE, M; San Francisco State University; *mahoney5@mail.sfsu.edu*

Pupation and Eclosion are Delayed Following Imaginal Disc Damage in Early Instar Larvae in the Hornworm, Manduca sexta

Tissue damage results in developmental delays in many organisms, putatively by delaying key developmental hormones, allowing for tissue repair. This is noted as pubertal delays in humans and metamorphic delays in holometabolous insects like the tobacco hornworm, *Manduca sexta* and the fruit fly, *Drosophila melanogaster*. Understanding how these delays arise can provide insight into how conserved the mechanisms of tissue repair are across animals. The aim of this study was to identify a "critical window" where tissue damage no longer caused delays in development in *M. sexta*. Larvae were irradiated with varying doses of x-rays at the beginning of the 3rd and during their last larval instar (L5), on days 1, 2, 3 or 4 after ecdysis. Timing to wandering behavior, pupation and adult eclosion were monitored. It was hypothesized that irradiation would delay pupal development if presented early in the last larval instar, but not later - after release of developmental hormones - and that larval molts would not be affected given the differences in the roles of developmental hormones at this time. Pupation was delayed after irradiation at the 3rd larval instar or at the beginning of the 5th larval instar within the 1st day after L5 ecdysis. Adult eclosion was significantly delayed irrespective of when the x-rays were administered. Delays in L3 larvae were only noted at higher irradiation levels. These results suggest a delay factor may inhibit key developmental hormones for pupation that are already released in the L5 stage after day 1. These delay factors, even when released at an earlier instar, will delay pupation and adult eclosion, but not larval molts. These data suggest the effects of tissue damage can have profoundly different results depending on the endocrine status of the organism.

P2-262 MAIE, T.*; CHRISTY, R.M.; MAIE, Takash; Univ. of Lynchburg, VA; *maie.t@lynchburg.edu*
Adhesive force and endurance during waterfall climbing in an amphidromous gobiid, Sicyopterus japonicus (Teleostei: Gobiidae): Ontogenetic scaling of novel locomotor performance
An amphidromous sicydiine goby, *Sicyopterus japonicus*, exhibits rock-climbing behavior during upstream migration along rivers and streams. Using the pelvic sucker, formed by fused pelvic fins, *S. japonicus* generates suction for adhesion on the climbing surface. By measuring performance variables that correlate to successful rock-climbing capability, we evaluated scaling relationships of suction force generated by the pelvic sucker and its fatigability during climbing in *S. japonicus* both with respect to body mass. During continuous climbing on the 60°-inclined surface, the pelvic sucker of *S. japonicus* exhibited a strong positive allometry in generating force for adhesion. In addition, during sustained adhesion, time constant as a measure of fatigue time for the pelvic sucker muscles scaled non-linearly with body mass and showed the best fit to a quadratic regression, the peak point of which predicted intermediate-sized individuals (large juveniles to small adults) to be the best in endurance performance during adhesion. Our experimental results indicate that different sizes of waterfall-climbing gobies have different performance capacities for rock climbing, relating to physiological differences in their pelvic muscles. In addition, our data from *S. japonicus* can indicate selection pressures on the locomotor capacities of waterfall-climbing gobiids vary during ontogeny.

100-3 MAIN, RP; Purdue University; *rmain@purdue.edu*
Solid and fluid mechanics in the skeleton: Dr. Mimi Koehl's undergraduate biomechanics course and my research career in skeletal mechanobiology.
Every day I tap into the knowledge base that Dr. Mimi Koehl laid for me twenty years ago in her undergraduate biomechanics course, Integrative Biology 135. This course and its dynamic professor steered me toward a career in comparative skeletal mechanobiology, where my research considers skeletal tissue mechanics across many length scales, from the whole bone to the single bone cell, utilizing principles of both solid and fluid mechanics. My group's research examining comparative skeletal plasticity in response to mechanical challenge in tetrapods has shown that there are different strategies by which bone tissue volume and second moments of area can be altered to produce stiffer long bones. Species differences in skeletal adaptive mechanisms may be modulated by differences in cell-level mechanical stimuli, which are caused by mineralized tissue deformations that induce pressure-driven fluid flow through nanometer-scale pores of the bone lacunar-canalicular network (LCN). The flow profile past the osteocytes residing in this network could exhibit characteristics of Poiseuille, Darcy, or Brinkman flow depending upon the geometry of the bone LCN and the dimensions of the protein fibers in the pericellular matrix. Differences in these flow profiles across different species or in pathological disease conditions could affect the mechanoresponsiveness of the skeleton to mechanical loading and consequently maintenance of adequate safety factors and the ability to resist fracture under continued mechanical loading. While I never worked in Dr. Koehl's lab and we never collaborated in our research, her foundational classroom lessons helped inspire me to pursue a life-long career in comparative skeletal biomechanics.

99-5 MALINGEN, SA*; CASS, JA; POWERS, JD; MA, W; IRVING, T; DANIEL, TL; University of Washington, Seattle, Illinois Institute of Technology, Chicago; *sage701@uw.edu*
In-vivo x-ray diffraction imaging of a synchronous flight muscle reveals thick filament stretching as a function of activation
The energetic efficiency and tuning of force generation in muscle cells depends on the dynamically changing architecture of the contractile machinery. Contraction is powered by myosin molecular motors that branch off of the thick filament and bind to the actin-containing thin filaments at specific binding sites. But these binding sites are not aligned to the molecular motors. This would result in a low binding probability for most of the myosin motors, except both the thick and thin filaments are compliant. Compliance means that binding sites and cross bridges can realign during contraction, tuning force generation as shown by spatially explicit models of the filament lattice. However the degree to which filament stretching occurs *in vivo* during cyclic loading remains unknown. Here, we use time-resolved x-ray diffraction techniques to directly measure the strain experienced by myofilaments of the synchronous flight muscles of the hawk moth *Manduca sexta* during cyclical loading *in vivo* (i.e. during tethered flapping flight). Any stretching of the thick or thin filaments is manifest as a change in the periodicity of their respective helices. We find that the thick filament backbone experiences strains in the range of 0.12% to 0.61% with a global average of 0.24% (N=7, an average of 0.18 Å in the helical pitch spacing), while layers of myosin crowns show a change in periodicity ranging from 0.03% to 0.42%, with a global average of 0.13% (N=7). Even this seemingly slight compliance can facilitate non-linear tension development, relaxation rates, and elastic energy storage, enabling efficient periodic contraction.

P2-81 MALTBY, R; NOURBAKHSH-REY, M *; MARKHAM, MR; University of Oklahoma; *rmaltby@ou.edu*
Metabolism Sensing Mechanisms in the Electric Organ Cells of a Weakly Electric Fish
Weakly electric fish navigate and communicate with electric organ discharges (EODs) produced by the coordinated action potentials of muscle-derived electric organ cells (electrocytes). EOD production incurs significant metabolic costs in the electric fish *Eigenmannia virescens* which reduces signal amplitude during food restriction. This effect is mediated by leptin, a peptide hormone that typically plays multiple central and peripheral roles in energy homeostasis. We hypothesized that, in addition to these functions, leptin is also regulating EOD amplitude in *E. virescens* by directly modulating electrocyte function. We found that electrocytes express a leptin receptor (LepR), and gene phylogeny groups the *E. virescens* LepR with those of freshwater teleost fish. Electrocytes also express an ATP-sensitive K^+ channel (K_{ATP}) complex that couples electrical excitability to metabolic status in a number of cell types including smooth and skeletal muscle. In many cases K_{ATP} is a downstream target of leptin. We cloned electrocyte K_{ATP} subunits and expressed them in *Xenopus* oocytes. Voltage-clamp experiments revealed an inwardly rectifying K^+ conductance that is enhanced by the metabolic inhibitor sodium azide. Gene phylogeny of *E. virescens* K_{ATP} indicates that the functional channel consists of Kir6.2 and SUR2B subunits. Because leptin receptors are known to be coupled to K_{ATP} channels in several other physiological systems, we hypothesize that electrocyte LepR and K_{ATP} channels form a signaling complex that couples metabolic state to signal output in *E. virescens*. Future experiments will test this hypothesis.

53-3 MALUL , D*; SHAVIT, U; HOLZMAN, R; Technion - Israel Institute of Technology, Haifa, Tel-Aviv University; *Malolds@technion.ac.il*

Dancing out-of-phase: mechanical properties of coral tentacles contribute to mass transfer under wave induced flow

Sessile marine organisms rely on ambient flow for nutrient supply and waste removal. Many cnidarians have flexible tentacles that sway and bend under the influence of waves and currents. Using high speed videography and PIV measurements, we recorded the flow and tentacle motion of three cnidarian species, *in-situ* and in a standing wave lab flume. Tentacles exhibited an unintuitive motion: they oscillated with the same frequency as the waves, but preceded the waves by around a ¼ of wave period, generating an out-of-phase motion. Our observations (>120) led to two research questions: 1. is there a benefit in out-of-phase motion, in terms of mass transfer? 2. what mechanism permits such motion? We used numerical simulations to estimate absorbance of dissolved oxygen from the environment to the tentacles in a wide range of phase differences. Our simulations show that the observed out-of-phase motion improves mass transfer by up to 2-fold compared to moving in-phase. We tested a simple mechanical model where tentacles were represented as mass-spring systems and used it to non-intrusively measure the spring coefficient of *Dipsastrea favus* tentacles (κ=1.13±1.24 [dyn cm / rad]). The model suggests the motion of tentacles is due to the mechanical properties of the tissue. We postulate that out-of-phase motion is a general phenomenon shared by cnidarian tentacles (and possibly other flexible marine organisms). Corals can modulate tentacle expansion, possibly indicating that they can adjust the spring coefficient and enhance mass transfer. Our findings demonstrate how these animals, often treated as immobile, can actively affect their interaction with the flow and harness wave motions to improve mass transfer.

109-3 MANGIAMELE, LA*; SMITH, SM; LECURE, KM; FUXJAGER, MJ; PREININGER, D; Smith College, Wake Forest University, Vienna Zoo; *lmangiamele@smith.edu*

Peripheral androgen action modulates foot flagging, but not vocalizations, in the multimodal display of the frog, Staurois parvus

Multimodal communication often requires coordination of multiple signaling systems, which may be subject to divergent selection pressures. Physical gestures are prominent in many species' multimodal displays. We have shown that selection for "foot flagging," a novel gestural signal in frogs, is associated with increased sensitivity to androgenic hormones in the spinal cord and hind limb muscles, similar to that found in the larynx of vocalizing frogs. *Staurois parvus* sexually displays with foot flags and vocalizations, therefore we tested whether peripheral androgens modulate both signals. We injected males with testosterone (T) plus Flutamide, a drug that blocks all androgen receptors (ARs), or T plus Bicalutamide, which blocks only peripheral ARs, and recorded the frequency of foot flagging and vocalizations. We found that both drugs inhibit foot flagging, which suggests that ARs in the peripheral muscles primarily influence this behavior. Surprisingly, and in contrast to many other anurans, we found that vocalizations do not appear to be androgen-dependent in male *S. parvus*. This result suggests that sexual selection may differentially influence the nervous and muscular tissues underlying different components of multimodal displays.

128-2 MANTILLA, DC*; TUCKER, EL; HSIEH, ST; Temple Univ., Philadelphia; *dcmantilla@temple.edu*

Kinematics of Specialist and Generalist Lizards Running on Level and Incline Granular Media

The natural world is rich with a variety of terrestrial substrates exhibiting complex behavior. For example, granular media (GM) solidifies and fluidizes during a single step making effective movement across its surface a significant challenge. Little is known about running performance and kinematic strategies used to navigate GM, especially at different inclines. Lizards are an excellent system to study because they are found in the desert moving across level sand and inclined dunes. We hypothesized that sand specialists would run faster than generalists when running on level GM, and would show less of a performance decrement when running on inclined GM. We ran sand and fluid specialists (zebra-tailed, *Callisaurus draconoides*; basilisk, *Basiliscus vittatus*) and a generalist (Eastern collared lizard, *Crotaphytus collaris*) across level and incline (31.5°: angle of repose) GM on a fluidizable bed trackway. We explored differences in running speed and determined how these are modulated via basic kinematic strategies. Lizards were filmed at 500 fps (Photron SA-3), and videos were analyzed in MATLAB. All three species increased stride frequency and shortened their strides when running on the incline. However, running performance differed by species. On the level, sand and fluid specialists ran faster than generalists ($F = 13.1$, $p<0.001$). On the incline, generalists ($F = 7.05$, $p = 0.01$) and fluid specialists ($F = 33.8$, $p<0.001$) ran slower, whereas desert specialists were unaffected ($F = 0.72$, $p = 0.39$). These differences suggest that while sand specialists can overcome foot slippage during material fluidization on the incline, fluid specialists and generalists cannot. This may be due to morphological specialization and/or kinematic adjustments, which require further exploration.

P2-83 MARKLAND, S*; ORTIZ ALVARADO, CA; TWOMBLY ELLIS, JF; CORDERO MARTINEZ, CS; SILVA ECHEANDIA, SA; PETANIDOU, TF; TSCHEULIN, T; BARTHELL, JF; GIRAY, T; AGOSTO RIVERA, JL; ABRAMSON, CI; Oklahoma State University, Stillwater, University of Puerto Rico Rio Piedras, Cornell University, Ithaca, New York, University of the Aegean, Mytilene, Lesvos, Greece, University of Central Oklahoma, Edmond; *sarah.markland@okstate.edu*

Honey Bee Shift Work in Comparison to Learning Behavior and Foraging Profiles

Apis mellifera, also known as the European honey bee, sometimes shows a bias toward specific colors of flowers. They can also show preferences for foraging at specific times of the day, i.e. morning or afternoon shifts. The question this research aims to explore is whether or not a bee who was particular in choosing a shift was also particular regarding decision making while foraging. Our hypotheses were that shift work would correlate with foraging behavioral patterns, and that bees would react to a decrease in flower reward by choosing the more reliable color of flower. Moreover, foragers may respond to variability and change flower preference or they may be constant to one type of flower. Bees that forage only at one time may also forage only on one type of flower. We set up two bee hives and taught them to visit feeders of sucrose water. The bees were then marked with different colors specific to hive and time of day to observe the shift work behavior. Then, the marked bees were followed in order to observe their decision making process when the reward of a particular color of flower, that had previously been experienced as consistent, was reduced while the other remained higher. We found that the bees fit in to one of four categories of foraging behavior, which did not correlate with their shift work preference. We also noticed that the number of morning bees and afternoon bees were not evenly distributed.

54-1 MARO, A/E*; SANDNEL, A/A; MITANI, J/C; DUDLEY, R; University of California Berkeley, University of Michigan Ann Arbor; *alekseymaro@berkeley.edu*

Ethanol concentrations within primate-consumed fruit in a tropical rainforest

Fruit represents a substantial portion of many animal diets, especially primates; chimpanzees consume 5-10% of their body mass in fruit per day. As fruit ripens, the saccharide-rich contents are exposed to ubiquitous Crabtree-positive yeasts, which fermentatively produce ethanol even in the presence of oxygen; such yeasts evolved in parallel with the origins and diversification of angiosperm fruit over 100 mya. Yeast-derived ethanol can deter bacterial competitors within the internal fruit environment, may facilitate fruit localization and thus seed dispersal via animal olfactory responses, and may also stimulate appetite via the psychoactive effects of ethanol. Naturally occurring ethanol concentrations in fruit are, however, largely unstudied. During field studies at Ngogo, Kibale National Park, Uganda, we measured ethanol concentrations in the pulp of 23 species of fruit, 22 of which are known to be consumed by chimpanzees. All fruit tested had detectable levels of ethanol, ranging from 0.02% to 4.34%; the fruit species in our study represent approximately 50% of the chimpanzee diet at Ngogo, and our results are consistent with chronic low-level dietary exposure in this primate species. The higher elevation of Ngogo (1400 m) also suggests, via the Q10 effect (wherein enzymatic rates of yeast are cut in half with a 10°C drop in average temperatures), that ethanol levels in primate-consumed fruit at lower elevations will be substantially higher. These data are consistent with prolonged evolutionary exposure of all hominoid taxa, including ourselves, to dietary ethanol.

P3-129 MARROQUIN-FLORES, RA*; MORTIMER, NT; PAITZ, RT; BOWDEN, RM; Illinois St U; *ramarro@ilstu.edu*

Cold-inducible RNA-binding protein may regulate gonadal development in the red-eared slider turtle

Temperature-responsive genes, such as those coding for heat shock proteins, play a vital role in embryogenesis. Cold-inducible RNA-binding protein (Cirp) is a heat shock protein present in the gonadal tissues of multiple taxa with a potential regulatory role in the sex-determining pathway. The red-eared slider turtle (*Trachmeys scripta elegans*) exhibits temperature-dependent sex determination (TSD), where thermal cues trigger gonadal differentiation during development. In *T. s. elegans*, Cirp is up-regulated concurrent with estrogen-inducing transcripts at female-producing temperatures. Intron retention has been proposed as a regulatory mechanism for sex-specific development, and RNA-binding proteins can regulate the retention of introns. As Cirp is an RNA-binding protein localized in developing gonads, we hypothesize that Cirp plays a regulatory role in gonadogenesis by impacting the stability of target transcripts via intron retention. *T. s. elegans* eggs were incubated under fluctuating temperature treatments and either held under conditions that should produce males, or given a simulated heatwave to induce female development. Gonads from embryos were dissected for immunoprecipitation and RNA-seq. Sequenced RNA product will be aligned to an internal transcriptome developed from published raw reads to identify the target transcripts. Target transcripts will be translated and aligned to the painted turtle (*Chrysemys picta*) proteome to identify alignment gaps that correspond to retained introns. Our approach will help us understand how Cirp responds to fluctuating temperature treatments, and how it may regulate the nuclear expression of reproductive genes.

49-4 MARSHALL, CD*; CULLEN, JA; AL-ANSI, M; Texas A and M University, Qatar University; *marshalc@tamug.edu*

Spatiotemporal Movement Patterns of Hawksbill Sea Turtles (Eretmochelys imbricata) in an Extreme Environment: The Arabian Gulf as a Living Laboratory for Investigating Organismal Response to Climate Change

Sea turtles are an interesting model system to investigate organismal responses to extreme habitats. In the Arabian Gulf, air and water temperatures regularly exceed 50ºC and 30ºC, respectively and marine habitats are hypersaline. Female hawksbill sea turtles in Qatar exhibit a significantly smaller body size and reduced fecundity due to life in this extreme environment. Our goal was to investigate movement and habitat use of hawksbills as part of a Qatari conservation program. Turtles were captured in-water by hand or on the beach post-nesting. Satellite tags were affixed onto the hard shells and deployed. A Bayesian state space model was used to calculate error-adjusted geolocations from Argos-derived movement tracks. We incorporated a behavioral switching model to provide insights into habitat use and GAMMs were used to investigate which abiotic environmental parameters were influential to movement. Hawksbills remained within the Gulf, but moved widely throughout the southern basin. Overall, turtles traveled directly and quickly to distinct shallow habitats and then remained in discrete regions for weeks at a time, presumably foraging. Sea surface temperature had the most significant effect on movement. During summer months, turtles consistently moved toward a steep drop-off consistent throughout the southern Gulf at the 30-40 m isobath. We hypothesize that turtles seek out thermal refuge in these areas since they coincide with the cooler waters of the southern Arabian Gulf loop current. The need to spend time in cooler, deeper habitat may negatively impact energy acquisition, growth and reproductive output.

P3-167 MARSHALL, AS; MULLINS, H*; URISTA, CY; DAVIS, JE; Radford University; *amarshall39@radford.edu*

Heterophil/Lymphocyte Ratio as a Measure of Immune Response in Humans Exposed to a Novel Microbiome

Much research has been done on the long-term adaptive consequences of migration; however, less attention has been focused on short-term health effects of human travel. When traveling, individuals may experience new environments and new microbiomes that impact their health. While this travel might be short-lived, there may be longer-term consequences. What happens to an individual's immune response when they are introduced to a new environment? How might this impact immigration patterns and spread of disease across native and immigrant populations? This research examined the physiological changes that a group of 16 North Americans in 2017 and 15 individuals in 2018 experienced while traveling in the Peruvian Amazon for three weeks. Specifically we examined weight, body temperature, and heterophil/lymphocyte ratio. These variables were measured before the expedition, at the end of the expedition, and after their return to the United States. All collected data was analyzed using ANOVA and PCA. Initial results suggest an increase in immune response without any documented illness and potential negative correlations between immune activity and weight loss. This may suggest that the human body will initiate an immune response simply from exposure to a novel microbial environment, not solely in response to illness.

P1-273 MARSHALL, SK*; MOSSOR, AM; SPAINHOWER, KB; DIGGINS, TP; SINN, BT; BUTCHER, MT; YSU, WVU; *ammossor@student.ysu.edu*

Phylogenetic and funtional evaluation of Xenarthran hindlimb structure

Morphological divergence in the forelimbs is often associated with functional habits exhibited by the Xenarthra as a clade, ranging from arboreal-suspension in sloths to terrestrial-digging in armadillos. We hypothesized that quantitative differences in hindlimb form also will be predictive of the lifestyles observed among xenarthrans. A total of 27 functional indices were calculated from 42 measurements of bone length, width, and depth from a sample of N=83 skeletal specimens (total: 19 species). All raw data were initially log-transformed to account for allometry. Index data were evaluated using Principal Component Analysis (PCA) and corrected with phylogenetic PCA to determine the osteological correlates among extant taxa, and were subsequently used to predict substrate preference and substrate use by discriminant function analysis. PCA on index data clearly separated sloths from armadillos in morphospace based on gracility versus robustness, respectively, of hindlimb skeletal elements, whereas these characteristics were intermediate in anteaters. With the exception of hip moment index (HMI) and tibial tuberosity index (TTI) being associated with generalized traits in mammals, separation patterns were largely similar after accounting for phylogenetic relatedness among taxa. The predicted memberships for substrate preferences and uses for each species almost invariably corresponded with their observed lifestyles, with several indices relating to knee articulation stability and ankle/limb mechanical advantage as the significant discriminating features. Overall, our assessments expand interpretations of limb form and functional habits exhibited among xenarthrans, and potentially identify several conserved traits related to fossorialty as well as morphological trade-offs between digging and climbing.

22-2 MARTILLOTTI, AW*; TSAI, P-S; University of Colorado, Boulder; *anthony.martillotti@colorado.edu*

An adipokinetic hormone acts as a volume regulator in the intertidal gastropod mollusk, Aplysia californica

Adipokinetic hormone (AKH) is a multifunctional neuropeptide in the gonadotropin-releasing hormone superfamily. In insects, AKH primarily acts to mobilize energy stores during times of high energetic demand, but it has been shown to have other effects. Data mining has recently shown the presence of AKHs within the lophotrochozoa, however, they remain poorly characterized. We have previously identified an AKH in an intertidal gastropod mollusk, the California sea hare (*Aplysia californica*), and named it ac-AKH. Our previous data showed ac-AKH induced acute weight loss, suggesting a role in volume regulation. The overarching goals of this study were to test the role of ac-AKH as a volume regulator and examine the mechanism by which ac-AKH induced the acute weight loss. Our results showed that ac-AKH reduced body mass, in part, through the reduction of hemolymph volume without altering hemolymph osmolality or specific osmolytes. The effect of ac-AKH on volume loss was enhanced by acclimation to a hyposaline condition. We further showed that *ac-akh* expression in a central ganglion was inhibited during a hyposaline challenge, and that the administration of ac-AKH partially reversed the increase in body mass, but not the hemolymph osmolality change, caused by a hyposaline challenge. These data collectively show that ac-AKH acts to regulate hemolymph volume, but not hemolymph osmolality, in *A. californica*. Importantly, our results highlight the functional divergence of this structurally conserved neuropeptide in the molluscan lineage.

94-1 MARTIN, R. P.*; DIAS, A.; SUMMERS, A. P.; GERRINGER, M. G.; University of Kansas, Whitman College, University of Washington, University of Washington; *RPMartin@ku.edu*

Variations in Bone Density within Deep-Sea Grenadiers (Macrouridae)

Abiotic factors of deep-sea habitats such as high hydrostatic pressure and cold temperatures act profoundly on organisms invading these realms. Many fishes use gas bladders for buoyancy, and species living in the deep-sea deal with increased gas compression and density in these highly pressurized systems. Despite this, many retain small gas bladders and may employ other adaptations to aid in buoyancy. One possible mechanism includes decreasing bone mineralization in dense skeletal tissues. To test if there is an association with bone density and depth, Micro-computed tomography scanning was performed on 11 species in the Family Macrouridae (grenadiers) spanning a wide range of habitat depths (100 to 7,000 m). Scans included two hydroxyapatite phantoms as known-density standards to correlate voxel brightness to bone density. Density was compared across four bones (i.e. 11th vertebra, pelvic girdle, lower jaw, 1st pterygiophore), across maximum depths, and within a phylogenetic framework. Bone density varied within macrourid specimens, with the lower jaw being significantly denser than other bones; and was highly variable between species. There was also no correlation between bone density and depth, or between bone density and phylogenetic relationships. Previous work examining adaptations in deep-sea fishes describes trends of reduced skeletal mass, but we found no correlation between bone density and depth in the wide-ranging grenadiers. This lack of correlation could be explained by other adaptations such as reduced skeletal elements or increased lipid storage that may supplement buoyancy in the grenadiers. It is also possible that the lack of bone loss with depth may be revealing a more complicated story. Given the variation and questions raised by this study, quantifying bone density across depth and phylogeny is worth a substantial investigation.

46-1 MARTIN, CH; University of North Carolina at Chapel Hill, University of California, Berkeley; *chmartin@unc.edu*

Performance, not competition, shapes the major features of adaptive landscapes: evidence from repeated field experiments and hybrid fitness in pupfishes

One of the most poorly understood evolutionary processes is the evolution of novelty. How do new species colonize novel ecological niches (i.e. empty fitness peaks) or begin to use existing structures for novel functions? The microendemic origin of sympatric scale-eating and molluscivore pupfishes on a single Bahamian island within a vast ocean of ecological opportunity across Caribbean hypersaline lakes provides an intriguing case study of this process. Repeated measurements of the fitness landscape in this environment based on hybrid survival and growth in field enclosures indicate that a complex adaptive landscape with multiple fitness peaks is driving diversification in this system. Traditionally, negative frequency-dependent competition is thought to underlie such disruptive selection. However, the stability of these fitness peaks across lakes, time periods, and different frequencies of competitors suggests that performance shapes the large-scale features of the adaptive landscape. Excessive gene misexpression in hybrids and reduced hatch rates also provide intriguing clues that genetic incompatibilities in these young species may impair the performance of hybrids, regardless of the number of competitors within field enclosures, and contribute to the long-term stability of interspecific fitness peaks in contrast to intrapopulation frequency-dependent dynamics. The origins of microendemic adaptive radiation may lie at the intersection of ecological opportunity, performance, complex fitness landscapes, and diverse sources of genetic variation.

S7-5 MARTINEZ, CM*; MCGEE, MD; BORSTEIN, SR; SPARKS, JS; WAINWRIGHT, PC; University of California, Davis, Monash University, University of Tennessee, American Museum of Natural History; *cmimartinez@ucdavis.edu*

Scaling Up Kinematics: A Geometric Approach for Studying the Evolution of Biological Motions

The study of kinematics explicitly integrates morphology and motion and is vital to our understanding of the evolution of functional systems. However, traditional analytical methods are generally suited for detailed comparison of relatively few taxa. We present a method for evaluating kinesis that treats complex biological motions as a single object, a trajectory of shape change, the properties of which make it amenable to comparative study. We focus on cichlid feeding systems, providing examples of two geometric-based motion analyses. First, we explore the relationship between prey capture kinematics and feeding ecology in African cichlids, using high-speed videos. We find that the amount of kinesis produced (trajectory length) and the efficiency at which it is done (trajectory nonlinearity) are linked to diet, both being greater in species eating more evasive prey types. Second, we introduce a framework for evaluating form-function relationships in biomechanical models, using an example from Malagasy cichlids. By simulating the movements of four-bar linkages, given some input rotation, we can produce motion trajectories as we did in live fishes. We propose that the resulting trajectory lengths may be used as an alternative functional metric to kinematic transmission (KT), a common measure of motion transfer in four-bars. This new metric has the desirable qualities that it measures total output kinesis of linkages and also that it is not ratio-based and therefore not subject to issues of artifactual redundancy previously shown for KT. Our research highlights the potential for geometric morphometrics to address novel questions involving the evolution of biological motions.

P2-154 MARTINEZ, E*; MENZE, MA; AGOSTA, SJ; EASTERN ILLINOIS UNIVERSITY, UNIVERSITY OF LOUISVILLE, VIRGINIA COMMONWEALTH UNIVERSITY; *emartinez9@eiu.edu*

The Hungry Caterpillar: Linking Mitochondrial Energetics and Life History Traits as a Function of Temperature in Manduca sexta.

The relationship between whole-organism growth and metabolism is generally assumed to be positive and causative; higher metabolic rates support higher growth rates. In *Manduca* sexta, existing data demonstrate a deviation from this simple prediction: at supraoptimal temperatures for larval growth, metabolic rate keeps increasing while growth rate is decreasing. This mismatch presumably reflects the rising "cost of maintenance" with temperature. Precisely what constitutes this cost is not clear, but we suspect the efficiency with which mitochondria harness oxygen and organic substrates into cellular energy (ATP) is key. We tested this by integrating existing data on M. sexta growth and metabolism with new data on mitochondrial bioenergetics across the temperature range 14^{o}C-42^{o}C. Across this range, our measure of mitochondrial efficiency closely paralleled larval growth rates. At supraoptimal temperatures for growth, mitochondrial efficiency was reduced, which could explain the mismatch between growth and metabolism observed at the whole-organism level. On a broader scale, this study suggests that the thermal plasticity and thresholds of mitochondrial ATP production are likely a major modulator of growth performance in holometabolous insect larvae.

71-8 MARUSKA, KP*; NIKONOV, AN; Louisiana State University; *kmaruska@lsu.edu*

Male Dominance Status Regulates Odorant-Evoked Processing in a Forebrain Decision Center of a Cichlid Fish

Ability to detect and identify odorants in the environment is crucial for survival and reproductive success. For species that breed seasonally or live in dominance hierarchies, plasticity in olfactory abilities associated with changes in internal physiological state has important consequences. However, whether olfactory processing in higher-order decision centers is influenced by an animal's physiological condition is unknown. We used in vivo single-unit and local field potential (LFP) recordings from a forebrain decision center (ventral telencephalon) in dominant and subordinate male cichlid fish to test the hypothesis that response properties of olfactory neurons differ with male social status. Dominant sexually-active males responded better to sex- and food-related odorants. In contrast, subordinate reproductively-suppressed males responded better to complex odorants from behaving dominant males, suggesting that olfactory signals from rivals may mediate social suppression and allow subordinates to identify opportunities to rise in rank. Odorant-evoked LFP spectral densities were also 2-3-fold greater in dominant males, demonstrating status-dependent differences in processing possibly linking olfactory and other neural inputs to goal-directed behaviors. Thus, high and low ranking males showed distinct odorant-evoked responses reflected by differences in both synaptic inputs (LFPs) and outputs (spikes), which match the behavioral needs of their status-specific lifestyles. For the first time we reveal social and reproductive-state plasticity in olfactory processing neurons of a vertebrate forebrain decision center. This neural plasticity revealed in the cichlid raises the possibility of similar mechanisms in other taxa to facilitate olfactory-mediated behaviors suited to an animal's current lifestyle.

120-2 MASS, S*; FUNK, A; PINSKY, B; MASSENA, K; CHABRIA, T; MINICOZZI, M; MLYNARSKA, I; MOODY, T; ST JOHN, P; SUNY New Paltz, Univ of Northern Arizona; *masss@newpaltz.edu*

Endocrine disruption, cytoskeleton and regeneration in planaria

Environmental xenoestrogens such as Bisphenol-A (BPA), have been shown to depress and delay regeneration in a variety of planarian species 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 estrogen receptor (ER)-like pathway in planaria. In vertebrate systems, weak 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 tubulin cytoskeleton in regenerating planaria exposed to BPA.

53-6 MATLOFF, LY*; CHANG, E; STOWERS, AK; FEO, T; JEFFRIES, L; THOMPSON, C; LENTINK, D; Stanford University, Smithsonian Institution, Division of Birds; *lmatloff@stanford.edu*

Feathers of a bird stick together: underactuation and directional adhesion in avian wing morphing

Birds morph their wings through continuous shapes to attain maximal flight performance and maneuverability. This seamless morphing happens through the movement of feathers, yet how they work together in a wing capable of robust flight is heretofore unknown. To gain insight into the underlying mechanisms that coordinate flight feathers, we take a multi-scale approach, measuring feather interactions at different hierarchical levels of organization. Kinematic measurements of common pigeon wings found that feathers move linearly with respect to the wrist angle during wing morphing, showing that feather coordination is an underactuated system controlled by skeletal motion. We then investigated neighboring feather interactions by measuring of pairs of feathers and the forces they exert on each other when separating in different directions. Only in the direction of wing extension, motion was locked, acting as end stops preventing separation. Microstructures on the interacting surfaces contribute to the directional adhesion effects. High-resolution micro computed tomography scans captured the curved morphology of the dorsal rami on the leading edge of flight feathers. We developed underactuated feathered robotic wings which we test in a wind tunnel under laminar and turbulent flow profiles as well as on a robotic platform in free outdoor flight. Together, underactuation and directional adhesion enable feathers to work in conjunction to coordinate wing morphing.

89-6 MATOO, OB*; JULICK, CR; MONTOOTH, KL; University of Nebraska- Lincoln, University of Nebraska-Lincoln; *omatoo2@unl.edu*

Mitochondrial and Organismal Metabolic Homeostasis in the face of Genetic Variation

The physiological and regulatory processes that maintain energy homeostasis may provide stability in metabolic trajectories despite underlying genetic variation in populations. However, at present, we lack a detailed understanding of the links between genome variation, mitochondrial energetics and organismal metabolic rate. Here, we tested whether metabolic strategies in the fruit fly *Drosophila melanogaster* varied among genotypes and across ontogeny for both wildtype and mitochondrial-nuclear genotypes that have compromised mitochondrial oxidative phosphorylation (OXPHOS). We found that the fundamental scaling relationship between mass and metabolic rate differed significantly across development in *Drosophila*. There was a switch in metabolic scaling from hypermetric scaling in first instars to hypometric scaling in third instars. We also observed that mitochondrial respiration was maintained in second- and third-instars at similar levels, despite a significant increase in oxidative capacity per unit of mitochondrial protein during development. Furthermore, we found that genotypes differentiated into two groups—those that switch to mitochondrial ATP production before the second instar and those that continue relying on glycolytic ATP through the second instar. Interestingly, the mitochondrial-nuclear genotype with compromised OXPHOS had compensatory up-regulation of both glycolytic flux and oxidative capacity of mitochondria. This up-regulation was coincident with increased ROS production during the second instar and reduced mitochondrial membrane potential compared to other genotypes. Taken together, the data reveal that genetic defects in core physiology can be buffered at the organismal level and that there may be multiple genotypic and physiological paths to equivalent organismal outcomes within populations.

15-1 MATSUDA, SB*; GATES, RD; MATSUDA, Shayle; Hawaii Institute of Marine Biology; *shayle@hawaii.edu*

The effects of thermal stress on Symbiodiniaceae assemblages in four Hawaiian coral species

Scleractinian reef corals live within a few degrees of their upper thermal limit. They exist in an obligate symbiosis with single-cell dinoflagellates in the family Symbiodiniaceae, however, thermal stress from episodic or seasonal ocean warming facilitates the breakdown of the coral-algal partnership (i.e., coral bleaching) that can lead to coral mortality. Algal symbionts (all formally classified in the genus *Symbiodinium*, now recently reclassified into many different genera) exhibit diverse functional traits that are integral to coral host nutrition, defense, and physiology, and effect the performance of reef corals during (and following) temperature stress. Here, we examine how Symbiodiniaceae 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 Symbiodiniaceae fidelity and transmission mode. Twelve genotypes per coral 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 recovery period) and treatment effects on microbial community assemblages were identified through amplicon sequencing of ITS2, and Symbiodiniaceae performance was assessed through PAM fluorometry, cell counts, and Chl-a. Our across species comparison of coral physiological performance with microbial communities offers clarity on the impact of Symbiodiniaceae in holobiont thermal tolerance as global climate change and ocean warming continue to threaten coral reefs.

91-3 MATTHEWS, DG*; LAUDER, GV; Harvard University; *davematthews@g.harvard.edu*

Fish median fin function studied using a simple robotic model

One hallmark of fish diversity is the position, number, and structure of the median fins. The role of these fins in both thrust production and maneuverability has been examined previously in a diverse group of fish species. However, assessing the effects of body stiffness, fin function, and fin-fin interactions on the cost of transport is challenging to do in live fish. While several groups of engineers have shown that airfoils in tandem are able to augment performance by recapturing wake energy, none of them have done so in a fish-like undulatory system. We created a set of biomimetic plastic foils with biologically relevant fin-to-body proportions as well as varying dorsal and anal fin position (near, far, or absent) to see if there is any change in performance when the motion and morphology are biologically constrained. Using a leading-edge flapping robot in a recirculating flow tank, we used both pitch and heave of the leading edge to actuate foils of two different stiffnesses at six frequencies (.5-3 Hz). We measured forces produced by the foils, phasing of the dorsal and caudal fins, and visualized water flow around the foils. These force data were used to calculate power consumption and efficiency, and we examined oscillation amplitude of forces during propulsion. Although stiffness had the largest effect on thrust production, there were significant effects of fin positioning at all frequencies. Foil shape also affected power consumption, efficiency, and smoothness of force production, measured as force oscillation amplitude. The relative effects of each fin position were highly dependent on the stiffness of the fin and the flapping frequency. Flow visualization of foils at the highest frequency showed that fin-fin flow interactions differed between foils and altered the angle of attack of flow over the caudal fin.

34-1 MATTHEWS, MG*; SPONBERG, SN; Georgia Tech; *meganmatthews10@yahoo.com*
The wind around moth wings: Can vortices in the environment disrupt the leading edge vortex?
Natural environments create unsteady airflow when wind interacts with flowers, trees, and other obstacles. Most small flying animals rely on coherent, but unsteady structures to maintain lift like the ubiquitous leading edge vortex (LEV). Many insects flap at Reynolds numbers where the LEV can burst while remaining attached to the wing, but this has not yet been observed on a freely behaving animal. Hawk moths hover feed at flowers and must interact with environmental disturbances including the flower wake. Using a robotic flower our previous work showed that maneuverability suffers most at the vortex shedding frequencies in the flower wake. Since flight dynamics are altered but overall hovering persists, is the structure of the LEV disrupted by interaction with shed vortices? We examined the structure and persistence of the LEV using smoke visualization over the wings and thorax of hawk moths in the roboflower wake. Although LEV bursting is expected at the Reynolds number relevant for hawk moth flight, the LEV in the flower wake remains bound throughout the wingstroke with no apparent bursting. The LEV also maintains the same qualitative structure seen in steady air. We continue to probe the limits of LEV structure and stability with a systematic exploration of vortex shedding in cylinder wakes.

15-7 MATZ, MV*; DIXON, GB; LIAO, Y; FULLER, ZL; University of Texas at Austin, Columbia University; *matz@utexas.edu*
Rampant cryptic speciation and environmental specialization in two massive coral species from the Florida Keys.
Broadcast-spawning coral species have wide geographic ranges, spanning strong environmental gradients, but it is unclear how much spatially varying selection these gradients actually impose. Strong divergent selection might present considerable barrier for demographic exchange between disparate reef habitats. Here, we investigated whether the cross-shelf gradient (nearshore - offshore - deep) is associated with spatially varying selection in two common coral species, Montastrea cavernosa and Siderastrea siderea, in the Florida Keys. We used 2bRAD to genotype 20 juveniles and 20 adults from each of the three reef zones, planning to look for signatures of selection occurring within a single generation. What we found instead was completely unexpected. Each species turned out to be composed of four (M. cavernosa) or even five (S. siderea) genetically distinct races, with gene flow between them highly reduced in 30-50% of the genome while being essentially unrestricted in the rest of the genome. Each species includes two sympatric races that are only found in the deep (20 m) habitat, while other races are found only in the shallower reefs (3-7 m). The two "shallow" races of M. cavernosa are also specialized for either nearshore or offshore: comparison between adult and juvenile cohorts indicates that cross-shelf migrants are 3 times less likely to reach adulthood than local recruits. In conclusion, cryptic genetic subdivision, often associated with environmental specialization, appears to be very common in these two coral species, which might in part explain why they are still ecologically successful in the Florida Keys. In addition, our results show that deep reefs cannot serve as refugia from climate change since corals there tend to be highly environmentally specialized.

52-6 MAURY, C; SEROTA, MA; WILLIAMS, TD*; Univ Jean Monnet, Saint Étienne, Simon Fraser Univ; *tdwillia@sfu.ca*
Phenotypic plasticity in diurnal activity and chronotype during parental care in European starlings (Sturnus vulgaris)
Circadian rhythms: cyclical patterns of gene expression, physiology, or behaviour on a diel time scale (24 hours cycles) are ubiquitous. Recent research on "wild clocks" has suggested that biological rhythms and chronotype might be linked to an individual's ecology and fitness. We used an automated radio telemetry system to determine patterns of activity and individual chronotype (onset/cessation of activity relative to civil twilight, CT) in female European starlings during parental care. Diurnal patterns of activity varied among breeding stages, e.g. females were relatively more active just prior to sunset (16.00-18.00) during incubation but were more active in the early morning (7.00-10.00) during chick-rearing. Females which failed during incubation were relatively less active between 16.00-18.00, compared with successful birds. Chronotype was highly individually-variable, e.g. chick-rearing females first became active 7-127 min after morning CT, with low- to moderate repeatability within breeding stages. Females that were active earlier in the morning were also active later in the evening during all breeding stages, contrary to the idea of "larks" and "night owls". There was a weak relationship between a) onset of activity during incubation and a female's laying date, and b) onset of activity during chick rearing and probability of initiating a second brood, i.e. timing components of phenotype. However, there were few effects of chronotype on current breeding productivity (number of chick fledged, provisioning rate); females that were active later than average produced chicks with higher mass. Furthermore, we found no relationship between chronotype and any measure of future fecundity and return rate (in year 2) or cumulative 2 year productivity.

P2-256 MAYERL, CJ*; BOND, LE; STRICKLEN, BM; GOULD, FH; GERMAN, RZ; Northeast Ohio Medical University; *cmayerl@neomed.edu*
The coordination of respiration and swallowing in preterm mammals
Endothermic animals such as mammals have high functional demands for both feeding and breathing. However, these two behaviors must be temporally separate because food must cross the airway in the pharynx. The ability to coordinate feeding and breathing is therefore critical to survival. Preterm infant mammals typically struggle to coordinate these behaviors, reflecting an immature nervous system. However, increased neuroplasticity in such infants suggests that they may be able to overcome problems coordinating breathing and swallowing as they age. To test this possibility, we compared the coordination of respiration and deglutition in preterm and term infant pigs longitudinally from birth to weaning. We found that term pigs exhibited substantial coordination between breathing and feeding from seven days old through weaning, and that they increased the delay of inspiration following a swallow as they aged, implying increased airway protection. However, preterm infants possessed no stereotyped breathing patterns related to the timing of the swallow when young and failed to develop such coordinated behavior throughout suckling. Our results indicate that some aspects of this immature nervous system are carried through infancy and may be manifest as animals wean and start eating solid food.

17-3 MAYERL, CJ*; CAPANO, J; MORENO, A; BLOB, RW; BRAINERD, EL; WYNEKEN, J; Northeast Ohio Medical University, Brown University, Clemson University, Florida Atlantic University; *cmayerl@neomed.edu*

XROMM analyses of differences in pectoral and pelvic girdle rotation between land and water in turtles

Limb girdle rotations can make important contributions to the locomotor performance of tetrapods by facilitating increases in stride length. Most previous studies of girdle rotations have focused on hindlimb function during terrestrial locomotion. However, the forelimb also has a critical locomotor role among tetrapods in water and on land, with a different means of attachment to the body that might impact its capacity for rotation. The pelvis functions as a single, fused element that articulates closely with sacro-iliac joints, whereas the left and right pectoral girdles are attached to the body via a muscular sling and a flexible cartilaginous attachment, and have the potential to move independent of one another. As a result, pectoral girdle rotations may actually be greater than pelvic girdle rotations. To test for such differences, we used X-Ray Reconstruction of Moving Morphology (XROMM) to compare pectoral and pelvic girdle rotation between walking and swimming in the semiaquatic turtle *Pseudemys concinna*. Both girdles rotated in both environments. As predicted based on differences in girdle morphology, the shoulder girdle rotated more than the pelvic girdle during both walking (forelimb ~ 39°, hindlimb ~ 18°) and swimming (forelimb ~ 36°, hindlimb ~ 9°). However, the effect of the medium on shoulder girdle movements was small, whereas pelvic girdle rotations during swimming were half the amount during walking. This suggests that body support plays a large role in determining the impact of pelvic girdle rotations, whereas muscular contraction may determine pectoral girdle rotations.

S3-9 MüLLER, UK*; BROWN, MD; BERG, O; California State University Fresno; *umuller@csufresno.edu*

Suction feeding without muscles: Estimating power requirements from flow for the traps of bladderwort, a carnivorous plant

Suction feeding is the most common feeding mode in large aquatic organisms. Previous studies on fish showed that suction feeding requires considerable power, leading fish to recruit axial muscles or use elastic energy storage. Having no muscles, carnivorous plants use elastic energy storage to power fast motion. Here, we focus on two bladderwort species, *Utricularia gibba* and *Utricularia australis*, which catch zooplankton prey in millimeter-sized suction traps. Bladderworts are among the smallest and fastest suction feeders, with trap gapes of around 0.2 mm (median diameter at the mouth) and times-to-peak-flow of less than 1 millisecond. In this study we quantify the flow in front of the traps, using particle image velocimetry, to estimate the power generated during capture events. We found that suction events generate flow speeds at half gape from the vestibule that range from 0.13 to 0.37 m/s with median speeds around 0.15 m/s for *U. gibba* and 0.25 m/s for *U. australis*. These flow speeds are two orders of magnitude higher than those observed in larval fish with comparable gape diameters. We also observed that the time to peak flow speed is one to two orders of magnitude lower in bladderworts than in comparable larval fish. This combination of higher peak flow speeds and higher accelerations leads to considerably higher power estimates than those obtained for fish. Animals can reach similar powers using elastic mechanisms, yet we do not know which constraints prevent larval fish from reaching similar suction performances as bladderwort traps.

75-2 MCALPINE-BELLIS, E. *; GIBB, A. C.; Friday Harbor Labs , Northern Arizona University ; *mcalpine.liz@berkeley.edu*

Color Change and Movement Analysis of the Pacific Staghorn Sculpin, Leptocottus armatus

Analysis of habitat preference affords us valuable insight into the ecology and behavior of organisms, as well as shedding light onto various strategies of predator avoidance. To study defensive strategies associated with habitat preference, and to better understand how behavior varies with fish size, we analyzed the movement patterns of an intertidal, sand-burying sculpin, *Leptocottus armatus*, in a size range of individuals collected from the Puget Sound in Washington. *L. armatus* employs a behavioral defense consisting of rapid lateral movement of the body and pectoral fins to bury itself in sandy substrate. We expected predisposition for this behavior to vary with fish size as small fish may lack the musculature required to displace sufficient sand to cover the fish's body. Fish provided with a variety of naturally available substrates spent the majority of their time in sandy substrate (relative to cobble), regardless of size and burial inclination. Consistent with our *a priori* expectations, complete burial was observed more frequently in larger fish and only when they were positioned on sandy substrate. We also found that, in addition to being less likely to bury, smaller fish moved further distances and more frequently during lab trials. Finally, we observed that *L. armatus* of all sizes have a remarkable ability to produce rapid color changes, a behavior that was previously undescribed. Color changes appeared to be used to mimic substrate pattern and texture, and were highly variable on an individual basis; however, larger fish appeared to be able to produce more complex color patterns, relative to smaller individuals.

P1-290 MCCANN, M*; LATTANZIO, M; Christopher Newport Univ.; *madison.mccann.13@cnu.edu*

Sex Differences in the Response to Recent Climate Change by a Sexually-Dimorphic Species

The growing threat of climate change to biodiversity has led to a surge in studies geared to understanding species' responses, particularly with respect to changes in mean body size. Yet although current theory predicts widespread climate-driven declines in the mean body size of numerous taxa, both size increases and stasis have also been observed, prompting a need for further inquiry into the factors underlying these alternative ecological responses. In particular, the potential for males and females to exhibit divergent responses to long-term climatic shifts has received scant attention. Here we evaluate the impact of recent climate change on adult body size of male and female sage brush lizards (*Sceloporus graciosus*) drawing from eight populations spread throughout the species' range. Historical data (1954-1996, n = 905) supported male-biased sexual size dimorphism (SSD) and a tendency for larger size in warmer as well as more seasonal and rainy habitats. Present-day data (2017, n = 229) however revealed a different pattern: namely, a lack of consistent SSD and a tendency for larger size in cooler as well as wetter habitats. Temporal shifts in size were primarily driven by temperature, followed by precipitation, with the greatest size increases in habitats experiencing greater overall climate shifts over time. Interestingly, the sensitivity of females and males to climate shifts diverged in a way that may explain their lack of present-day SSD. Overall, we conclude that climate change may also favor larger body sizes (particularly when accounting for temperature and precipitation shifts), and that sex-specific climate responses may override expected patterns of SSD and body size evolution in a species.

P3-23 MCCARTY-GLENN, M*; SYED, S; MEHTA, RS; WARD, AB; WARD, Andrea; Adelphi University, Univ. of California, Santa Cruz; *award@adelphi.edu*

How substrate impacts terrestrial locomotion in American eels

American eel (*Anguilla rostrata*) populations have been threatened due to a number of factors including dams which can block the upstream migration. However, like many elongate fishes, American eels can move between bodies of water by either climbing a dam wall or leaving the body of water to circumnavigate the dam. In this research, we tested American eels moving across three different substrates: hard-packed sand, small loose pebbles, and small fixed pebbles where the pebbles were glued to each other and the container. We found significant interactions between substrate and location along the body. On hard-packed sand, American eels had the lowest distance ratios and velocities, especially along the middle of the body. Both the distance ratios and velocities were similar across substrates at the head and tail of the animal. Wave amplitude and frequency were found to differ across the body, but not between substrates. This study will provide additional understanding to how best to open up migratory pathways for American eels through the development of eel passageways.

60-4 MCCASKEY, EN*; LEHNER, K; MURRAY-COOPER, M; OZKAN-AYDIN, Y; HAWKES, EW; BENFEY, PN; GOLDMAN, DI; Georgia Tech, Duke University, UCSB; *emccaskey3@gatech.edu*

Circumnutation Facilitates Effective Root-Surface Exploration of Rice Roots

Circumnutation is a pattern of undulatory growth observed in a diversity of plants and their organs, including roots. Little is known about the function of below-ground circumnutation, particularly in root-surface interactions. Root tip traits that allow for seeking out cracks or biopores may be advantageous, as roots have been shown to utilize these traits to penetrate into deeper soil strata. Understanding function of root circumnutation can not only help with crop breeding, but also can give insight into schemes for robots to navigate in constrained environments with minimal sensing. After observing a root coiling phenotype on flat surfaces in non-circumnutating mutant rice roots, we hypothesized that root tip circumnutation facilitates effective root-surface exploration. To test this, plates were made with holes equally spaced at different densities to systematically model a surface environment of a compact soil horizon with biopores. Mutant and wild-type (WT) rice were grown in a clear gel-based media and a high-throughput automatic imaging system acquired images to visualize the root growth. As hole density decreased, mutant primary roots showed reduced success (below 50%) in finding a hole. WT primary roots had higher success (above 80%), indicating circumnutation leads to effective flat surface exploration. We have begun to test such strategies in a macroscopic pneumatically controlled planar soft robotic root. The novel design enables the robot to extend from its tip, modeling root growth. Further, the robot possesses side-wall elements which enable tip undulation via periodic pressure changes. Future studies of the robot will test penetration probability varying nutation parameters.

6-2 MCCLAIN, MA*; GALLAGHER, AJ; HAMMERSCHLAG, N; DRYMON, JM; GRUBBS, RD; SMUKALL, M; GUTTRIDGE, TL; DALY-ENGEL, TS; University of West Florida, University of Miami, Mississippi State University Extension, Florida State University, Bimini Biological Field Station, Florida Institute of Technology; *mam171@students.uwf.edu*

Connectivity and Relatedness in Tiger Sharks (Galeocerdo cuvier) between the Gulf of Mexico and West Atlantic

Shark dispersal for the purposes of reproduction is generally poorly understood, including that of tiger sharks (*Galeocerdo cuvier*), a large, circumglobal, coastal-pelagic species. Learning more about the dispersal patterns of apex predators, like the tiger shark, will allow for greater understanding of the conservation measures needed to protect this species and those like it. To gain insight into the reproductive evolution of these sharks, we have collected *G. cuvier* tissue samples from eight sites across the Gulf of Mexico and West Atlantic. We use highly polymorphic microsatellite DNA fragment analysis to examine relatedness of individuals within and between ocean basins, and use assignment testing to identify potential distribution corridors and critical habitat. Based on dispersal patterns observed in other large coastal shark species, we hypothesize that there will be shallow structure between the different sample sites due to geographic, environmental, and reproductive barriers. We further hypothesize that this structure will be male-biased, reflecting the female philopatry and dependence on coastal nursery habitat.

2-6 MCCOY, D. E.*; SHULTZ, A. J.; VIDOUDEZ, C.; VAN DER HEIDE, E.; TRAUGER, S. A.; HAIG, D.; Harvard University, Cambridge; *dakotamccoy@g.harvard.edu*

The Corruption of Honest Signals: from Mate Choice in Red Birds to Human Pregnancy

Mate choice is an evolutionary examination, where females select males who pass a test of quality based on proxy measures (such as bright orange feathers). Herein, we report deceptive elements to honest signaling in carotenoid-colored birds, compare this to the same phenomeon in embryo selection, and reference similar findings from the social sciences. First, we use scanning electron microscopy (SEM), liquid chromatography-mass spectrometry (LC-MS), and spectrophotometry to comprehensively quantify coloration from microstructures and pigments in the tanager genus *Ramphocelus*. We find four indicators of deceptive elements to this signal; for example, males (but not females) evolved elaborate microstructures to amplify colors, and males and females within a species have equivalent amounts and types of carotenoids (which is surprising if they are honest-because-costly). We propose that males have an evolutionary incentive to mate regardless of quality, which may lead to the corruption of honest signals. Mate selection is analogous to embryo selection: maternal bodies test proxy measures of embryo health, which are corrupted through selection on the differing interests of parents and offspring ("parent-offspring conflict"). In fields such as health care and education, Campbell's and Goodhart's Laws state that once a measure becomes a target, it ceases to be a good measure. For example, test-taking ability supposedly measures school quality, but also determines school funding. This may cause "teaching to the test," where the proxy (test-taking) improves but educational outcomes stay the same or worsen. Through mate choice, embryo selection, and Campbell's/Goodhart's Laws, we show that honest signaling is susceptible to some degree of corruption.

P2-69 MCCRACKEN, A.R.*; DABE, E.C.; MOROZ, L.L.; Wesleyan University, University of Florida; *amccracken@wesleyan.edu*

Neuronal Cell-type Homologies and Nervous System Innovations in Euthyneuran Molluscs

Euthyneura molluscs provide a unique opportunity to study the homology and evolution of nervous systems on a cellular level because these animals have the largest neurons in the animal kingdom. Since the Cambrian expansion, molluscs have undergone multiple independent nervous system centralization events where clusters of neurons have fused or been lost. In contrast, the serotonergic Metacerebral Cells (MCCs) are functionally and morphologically conserved across 380 million years of evolution, the longest traced single neuron homology in any system! Yet, little is known about the genetic homology shared between Euthyneura. To address this, we compared CNS, ganglia, and single neuron transcriptomic data from *Pleurobranchaea californica* to the genomic and transcriptomic data from the classic Euthyneura neuroscience model *Aplysia californica* and to other close and distant relatives. BUSCO analysis revealed 94% conservation of metazoan single copy orthologs in the *P.californica* hybrid assembly suggesting that we have constructed a reference transcriptome of near genome quality. Neuropeptides are diverse fast-evolving signal molecules that regulate physiological processes and behavior. Manual annotation of neuropeptides revealed that out of the Euthyneura evaluated, *P.californica* had the fewest shared neuropeptides with *A.californica*. Overall, the MCC transcriptome profile was highly conserved across species with orthologs found for transcription factors, ion channels, neuropeptides and the serotonergic biosynthesis genes. We also found numerous innovations in gene expression at the ganglia and single neuron levels, altogether allowing for a better understanding of how brains, novel circuits, and behaviors have evolved.

P3-118 MCCRARY, MB*; DUNCHEON, EJ; ALLEN, HC; O'KEEFE, JM; CHAMPAGNE, AM; University of Southern Indiana, The Ohio State University, Indiana State University; *mbmccrary@eagles.usi.edu*

Molecular interactions in bat skin suggest convergent evolution with birds

The outermost layer of skin, the stratum corneum (SC), protects the body from mechanical abrasion, pathogens, and excessive water loss. The SC is 10-20 µm thick and is composed of corneocytes embedded in a lipid matrix. These lipids help maintain the barrier function of the skin, and in most mammals consist of ceramides, free fatty acids, and cholesterol. However, bat SC contains a more diverse group of lipids including cerebrosides, ceramides with a sugar moiety attached to the headgroup. This lipid composition resembles avian stratum corneum, and may indicate convergent evolution between bats and birds. We used infrared spectroscopy to investigate the conformation of lipid chains in the SC of the big brown bat (*Eptesicus fuscus*) at 5° intervals from 15-50° C. Additionally, we exposed the SC to different vapor pressures and measured changes in hydrogen bonding properties as a function of hydration. We found that lipid chains in bat SC respond to temperature in a manner more similar to lipids in avian SC than lipids in the SC of most mammals. Furthermore, the presence of cerebrosides may affect hydrogen bonding interactions between lipids and water in the SC. The similarities between bird and bat SC may be a result of selection to maintain barrier function while simultaneously meeting the mechanical demands of flight.

P1-95 MCCUE, M.D.*; KLOK, J.; LIGHTON, J.R.B.; Sable Systems International; *mmccue@sablesys.com*

Running mice increase their metabolic rates, but don't increase rates of lipid oxidation

Moderate intensity exercise in humans consistently causes increases in metabolic rates, and thankfully, also increased rates of lipid oxidation. Interestingly, it is not uncommon for a standard laboratory mouse consuming a diet with >5% lipid content to voluntarily run as much as 3 km per day when provided with a running wheel. Changes in RER are often used to infer shifts in oxidative substrates, but such changes are difficult to reliably quantify during short term bursts of activity (e.g., 20-60 seconds) on a running wheel. In order to reliably document changes in oxidative fuels we designed a treadmill respirometry system with reduced time constant to document rapid changes in respiratory gases. Subadult mice were switched from a control diet to one that was supplemented with a stable isotope labeled fatty acid (^{13}C-palmitic acid; 4g/kg chow) for one week in order to enrich their body lipids. Mice were fasted for 1 h prior to experimental trials to minimize the assimilation (and subsequent oxidation) of recently ingested nutrients. We then measured the metabolic rates (VCO_2) as well as the isotopic enrichment (δ^{13}C) of mice for 5 minutes prior to exercise and during a 7-min bout of exercise at a speed of 15 m/min, and found that VCO_2 increased by over 50% during the first minute of exercise and leveled out during continued exercise. Rates of oxidation of endogenous palmitic acid (calculated from the (δ^{13}C in the exhaled breath) increased by 40% during the first minute of exercise; however, these values rapidly decreased, and during the last minute of exercise they were not statistically different from the resting state. These results suggest that unlike humans, mice do not fuel sustained, short-term locomotor activity using endogenous lipid stores.

P3-165 MCDONALD, JY*; LUSK, E; SAVICI, S; CASTO, JM; Illinois State University; *jmcdona@ilstu.edu*

Ectoparasites, Developmental Trade-offs, and Inflammation

In cavity-nesting songbirds, blood-feeding ectoparasite infestations can induce developmental trade-offs among somatic growth, physiological maturation and immune function. To grow and reproduce, ectoparasites require blood meals, which may be costly to host chicks, yet few studies have assessed which consequences of blood meals might induce developmental trade-offs. Previous research in European starlings (*Sturnus vulgaris*) suggests that Northern fowl mite (*Ornithonyssus sylviarum*) infestations produce effects on nestling phenotypes that are not simply mimicked by experimental blood loss. Perhaps mites also induce energetically costly acute phase responses in host chicks, characterized, in part, by increased proinflammatory cytokine production. We experimentally manipulated Northern fowl mite abundance and experimental blood loss in starling chicks and assessed chick survival, somatic growth, physiological maturation, and plasma concentration of the proinflammatory cytokine interleukin 6 (IL-6), to assess whether inflammation intensity covaries with these other variables. Nests were assigned to one of three treatments: permethrin-induced mite reduction, experimental blood loss, or mite enhancement. We assessed somatic growth of chicks at 5, 10 and 15 days of age. At these ages, blood was also collected to assess hematocrit, hemoglobin concentration, and inflammation via an IL-6 enzyme immunoassay. In chicks from the experimental blood loss group, additional blood was also collected as part of their experimental treatment. Preliminary results suggest that, relative to the other treatments, mite enhancement produced lighter chicks, and slowed physiological development. These data will be presented and discussed along with data on plasma IL-6 concentrations and nestling survival.

P2-54 MCDONALD, MS*; COHEN, JH; PORTER, ML; University of Hawai'i at Mānoa, University of Delaware; *marisam7@hawaii.edu*

Visual physiology of the grass shrimp Palaemonetes vulgaris

Grass shrimp of the genus *Palaemonetes* are visual animals, which use their eyes for predation, defense, and orientation. However, work on their visual physiology is dated and comparative studies on sympatric species are absent. This study aimed to investigate the visual physiology of *Palaemonetes vulgaris* through the use of electroretinogram (ERG) recordings. ERG data was used to model multiple spectral classes in shrimp tested under dark and orange chromatic adaptation and assess irradiance sensitivity with V-logI curves. *P. vulgaris* were found to be dichromatic, consistent with earlier work that described a broad peak at 540 nm and a narrow peak at 390 nm. The primary peak was clearly seen in dark-adapted animals in the green spectrum at 531 nm. Under orange chromatic-adaptation a UV peak emerged at 390 nm. As well as being a narrower peak shape, there was a 10 nm wavelength discrepancy in the peak wavelength of the green visual pigment compared to earlier work. The UV visual pigment was consistent with previous studies. In addition to spectral sensitivity, irradiance sensitivity measurements were taken at 530 nm in *P. vulgaris*, as well as in the closely related species *P. pugio*. These species are found sympatrically, but tend to separate by salinity and substrate in their natural habitats. We found that there is no significant difference between the irradiance sensitivities of the two species when they are maintained in the same conditions. Thus, any differences in habitat do not appear to be reflected in visual physiology.

28-6 MCELMURRAY, P*; BELL, S; CATHEY, S E; JUSTUS, S R; CREED, R P; BROWN, B L; Virginia Tech, Virginia Tech / University of Alabama, Appalachian State University; *pmac@vt.edu*

Colonization Tradeoffs in Symbioses: A Collection of Interesting Hypotheses

Symbiosis is an integral part of life, with most organisms on Earth engaged in symbiotic interactions ranging from mutualistic to parasitic. Classic studies into symbioses looked at simple pairwise interactions, like clownfish and sea anemones or pearlfish and sea cucumbers. However, focusing on these pairwise interactions ignores the ways in which complex communities of hosts and symbionts affect each other. Symbiosis research has not yet taken full advantage of metacommunity theory, which describes interactions between spatially disparate communities of organisms affecting each other through dispersal. Traditionally, this paradigm has been used to study communities along connected environmental patches. However, if we consider a host to be a patch, we can use metacommunity theory to study how host controls, symbiont interactions, and dispersal affect the structure and diversity of symbiont communities. We have developed a framework based on classical tradeoffs in community ecology to help understand and categorize the attributes of both host and symbiont organisms that lead to successful maintenance of a symbiosis. We propose that most of the diversity in regional symbiont communities (i.e. between hosts) is maintained by the colonization ability of a symbiont trading off with traits that increase symbiont fitness on a host, such as competitive ability, fecundity, and interaction intensity, as well as traits of the individual host and the abiotic environment. We have also used this framework to demonstrate the ways global change can decouple symbioses.

81-6 MCELROY, EJ*; MCBRAYER, LD; College of Charleston, Georgia Southern U.; *mcelroye@cofc.edu*

Defining acceleration performance during burst locomotion in running animals

Maximum speed and peak acceleration are important performance traits for understanding variation in the evolution of morphology, biomechanics, ecology and behavior. Many animals rely on quick bursts of locomotion when escaping predators and capturing prey. Hence strong selective pressures can occur on these traits. A variety of methods can be used to measure maximum running speed and, in general, we have a high degree of confidence in our ability to accurately and repeatedly estimate maximum speed. Estimation of peak acceleration is frequently achieved via high speed video and can be quite inaccurate depending on the details of video capture and the method used to smooth and compute the second derivative of the displacement data. Other methods, such as force plates and accelerometers, allow for more direct estimates of acceleration but have various limitations. We argue that we can avoid estimating peak acceleration, and the issues associated with its estimation, by redefining acceleration performance. A burst locomotor event is a movement that starts from a standstill and involves an accelerative phase up to a maximum speed. Limbed animals achieve such movement by cycling their limbs wherein each footfall results in a substrate reaction force that causes the animal to accelerate forward and gain speed. In this context, it is the speed gained per step and the number of steps that principally determine maximum speed. Acceleration performance can thus be defined as the per step gain in speed, which can accurately be estimated by overlaying footfalls onto the velocity curve. This definition of acceleration performance avoids the errors associated with computing acceleration from video-based displacement data and is linked to how step-based accelerations generate maximum running speed.

66-1 MCENTIRE, K D*; MAERZ, J C; HOWARD, J S; Trinity University, University of Georgia; *kmcentir@trinity.edu*

Plant Climbing by Salamanders as a Compensatory Behavior in Relation to Climate

Developing rigorous ecological models is a fundamental goal of ecologists to forecast biotic responses to climate change. Many models are amechanistic and lack integration of behavior, but behavioral plasticity is increasingly recognized as an important adaptive mechanism for species. We integrated biophysical and agent-based models to examine how climbing behavior could affect the sensitivity of Plethodontid salamander activity time to climate. We used a temperature differential to stimulate plant climbing, which reduced body temperatures and dehydration rates. The model showed climbing plants increased activity time in drier conditions, particularly for smaller salamanders. The predicted importance of climbing behavior was highly sensitive to assumptions about the threshold of water loss an individual was willing to tolerate. Because activity time is associated with fitness, increased activity time could moderate overall sensitivity to shifts in weather patterns. To test whether thermal gradients predicted plant climbing, we collected repeated count data on terrestrial salamanders in the southern Appalachian mountains across a range of microhabitats and weather conditions. The probability a salamander was observed climbing increased with greater soil temperature relative to air temperature, which was consistent with model predictions of plant climbing as a compensatory behavior to extend activity. Compensatory behaviors, like climbing, have the potential to moderate the effects of weather on salamander activity and fitness, which may dampen population sensitivity to climatic variation in rainfall or soil moisture. We used the field data to parameterize preliminary climate change models including climbing as a compensatory behavior.

86-5 MCGLASHAN, JK*; THOMPSON, MB; JANZEN, FJ; VAN DYKE, JU; SPENCER, R-J; Western Sydney University, University of Sydney, Iowa State University, Charles Sturt University ; *j.mcglashan@westernsydney.edu.au*

Synchronous hatching in freshwater turtles: metabolic and endocrine mechanisms

Synchronous hatching is a form of environmentally cued hatching (ECH) which allows embryos to alter hatching time in relation to the environment through phenotypic plasticity. In some turtles, synchronous hatching results from metabolic compensation or early hatching, and has evolved to reduce variation in clutch incubation time and increase an individual's chance of survival. Hormones likely play a critical role in enabling metabolic compensation and early hatching. Thyroid hormones and glucocorticoids regulate embryogenesis and are vital during birth/hatching events in many species. I compared the metabolic and endocrine mechanisms of hatching synchrony in freshwater turtles. Hormone analyses indicated there was no difference in triiodothyronine (T_3) and corticosterone concentrations during asynchronous development but concentrations increased in the yolk of the developing embryos towards the end of incubation, which coincides with hatching. There was a clear physiological response to exogenous T3 applications, which caused neonates to hatch earlier than expected but with no developmental or metabolic costs. These hormones might not regulate metabolic compensation, but they are likely important for synchronous hatching. Comparing the mechanisms used to synchronously hatch will further improve the understanding of the different ways in which ECH has evolved in reptiles.

P1-281 MCGRATH, SC*; GEISINGER, R; CARTY, W; SCOTT, K; MOORE, G; LANDBERG, T; Arcadia University, Arcadia Universtiy, Alfred University, Arcadia University ; *smcgrath_01@arcadia.edu*

Effects of Farming Practices and Animal Husbandry on Bone China Quality

Bone quality varies greatly within and between species for evolutionary, ecological, and developmental reasons. Diet and exercise may also influence the material properties of live bone by affecting the structure and composition of the primary bone minerals, calcium and phosphorus, as well as trace elements such as zinc, potassium, lead, and manganese. We use atomic absorption spectroscopy and scanning electron microscopy and material testing to determine how animal husbandry practices used to raise cows impact the chemical composition of cow femurs. From there, we transform the bone into bone china, a high-quality ceramic material made from 50% bone ash (the inorganic mineral component of bone), kaolin clay, and feldspathic mineral. When bone china is produced from cows that are free-range and grass-fed, the ceramic material is high-quality- white, translucent, and strong. However, when bone china is produced from industrial sources or bones of cows that are raised in small factory farms and primarily grain-fed, the bone china appears of lower quality- tinted yellow or off-white, has greater opacity, is more fragile and melts at lower temperatures. Preliminary results of the factory-farmed animal bone show the presence of whitlockite, a possible indicator of metabolic bone disease. Whitlockite incorporates iron and manganese into the hydroxyapatite structure which may explain the poor quality and low performance of grain-fed bone china. Our preliminary research suggests that bone china has extreme potential to reflect many aspects of biological variation by expressing not just our agricultural practices, but our values. Variation of this historic material has potential application in many forms including in industry, prosthetics, craft, and art.

88-5 MCHENRY, M/J*; SOTO, A; PETERSON, A; JOHANSEN, J/L; LAIO, J/C; UC Irvine, NYU Abu Dhabi, Univ. of Florida; *mmchenry@uci.edu*

How fish predators pursue evasive prey

Predation is a fundamental interaction between species, yet it is largely unclear what behavioral strategies are employed by predators. As a consequence, it is generally unknown what metrics of sensory and locomotor performance on a predator's approach matter most to predation. We have conducted experiments that measure the kinematics of piscivorous interactions under laboratory conditions in the interest of testing models of strategy. Separate studies on bluefish, lionfish and zebrafish indicated that fish predators generally use a strategy of pure-pursuit, which is distinct from the parallel navigation employed by aerial predators. This pursuit strategy requires relatively little sophistication in sensing and motor control on the part of the predator, which may be appropriate to the limitation of visually-guided behavior in an aquatic environment. This work has the potential to provide a basis for considering predation during a predator's approach.

S7-7 MCHORSE, BK*; BIEWENER, AA; PIERCE, SE; Harvard University; *bmchorse@gmail.com*

Modeling the Causes and Consequences of Digit Reduction in Extinct Horses

Digit reduction is common in vertebrates, from theropods to marsupials. Extant horses (Equidae) are the most extreme living example, with a single digit on each leg. Although the evolution of a single toe is remarkable, the selective driver has rarely been quantitatively tested. The structural modifications necessary for high-performance locomotion on a single digit are also under-explored. Our work combines ecological, biomechanical, and phylogenetic comparative methods to investigate the evolution of digit reduction from multiple angles. The loss of side toes in horses has long been posited as a response to the spread of grasslands in the Miocene. Our work modeling niche overlap and diversification dynamics shows a more complicated story, though: at broad temporal and spatial scales, three-toed and single-toed horses are not found in significantly different habitats, yet speciation and extinction rates across equid lineages do correlate with environmental shifts. Furthermore, lineages with reduced digits show lower extinction rates, suggesting some adaptive role. On an individual level, we have also demonstrated how positive allometry in the center digit can compensate for loss of important weight-bearing function in the side digits, which may have been a response to increasing body size or pressure for improved locomotor economy. Integrating methods from multiple fields has begun to reveal the complexity of digit reduction in equids, lending support to some historical hypotheses (such as the influence of body size) and rejecting others (such as habitat partitioning at a broad scale). Data from individual disciplines can answer small pieces of the evolutionary puzzle of digit reduction, but a holistic answer requires synthesizing data—both big and small—from multiple fields.

P2-218 MCINERNEY, MG*; STAAB, KL; McDaniel College, Westminster, MD; *mgm005@mcdaniel.edu*

The Structure and Composition of the Kinethmoid and Attached Ligaments in Cypriniform Fishes

Fishes in the order Cypriniformes are characterized by having a sesamoid bone in the upper jaw called the kinethmoid. The kinethmoid is attached to the maxillae, premaxillae, palatines, and neurocranium by ligaments that are responsible for transmitting muscular forces to protrude and retract the jaw during feeding. Each ligament is composed of differing types of connective tissues, and we examined the morphology and composition of the tissues from a functional perspective. We used histology to describe the morphology of the elements in the upper jaw of four cypriniform species, the goldfish, *Carassius auratus,* zebrafish, *Danio rerio,* rosy minnow, *Pimephales promelas,* and tiger barb, *Puntigrus tetrazona*. Using both quadruple and quintuple staining methods, we were able to identify the structure of the kinethmoid and ligamentous connections in addition to the types of cartilage-like connective tissues present. The premaxillary ligament is composed of hyaline-cell cartilage, a tissue with densely packed cells and little extracellular matrix. Both the palatine and maxillary ligaments resemble mammalian ligaments by having fusiform-shaped cells in a matrix with parallel fibers, but the palatine ligament extends more rostrally during protrusion and contains elastin, which may function to retract the jaws. Additionally, the kinethmoid stains differentially for both high and low tensile collagen where the low tensile region is located towards the interior of the bone while the high tensile region is on the periphery. Through our research, we can work towards a more complete understanding of the biomechanics of kinethmoid-mediated premaxillary protrusion.

81-2 MCINROE, B*; LIBBY, T; KODITSCHEK, DE; FULL, RJ; UC Berkeley, U Washington, U Penn; *bmcinroe@berkeley.edu*

Identifying Control Modules in Complex, Dynamic Behaviors by Using Ground-righting in Geckos

Animals can synergistically employ multiple appendages and body segments to perform behaviors. We hypothesize that these controllable components can be represented by sets of simple models (templates) that can be recruited in series or parallel to provide multiple strategies for executing a maneuver. To further define our conjecture, we measured self-righting in geckos, *H. frenatus*, on flat, rigid surfaces. Geckos self-righted successfully with average righting times of 0.22±0.03 *s* using complex dynamic appendage and body motions including body bending/torsion, limb/tail ground contact, and coronal plane tail sweeps qualitatively similar to those observed in inertial air-righting. To attempt to isolate control modules, we allowed geckos to right on a partially excavated rigid surface, where only the torso and legs, but not the tail, could make ground contact. Geckos still righted successfully without tail contact, but the average righting time increased by 40%, except when geckos used a different strategy, swinging their tails in the direction opposite to body rotation. Recruiting the tail inertial control module resulted in righting performance comparable to tail contact with average righting times of 0.19±0.02 *s*. Gecko body-level behavior appeared invariant to the dichotomy in tail strategy, with shoulder rotation preceding hip rotation. From these experiments, we begin to develop composable templates for quadrupedal terrestrial righting, start to validate these models through dynamic simulations, and explore possible feedback control strategies for bio-inspired robots. Our results suggest that geckos employ the tail as a multifunctional motor module in parallel with a body torsion template to increase robustness to challenging environmental substrates.

40-6 MCKEE, AA*; MCHENRY, MJ; Univ. of California, Irvine; *amberle.mckee@gmail.com*

How zebrafish use visual cues to evade predation

Predator evasion in fish is primarily facilitated by visual detection of a threat. In order to understand how prey fish evade predation, it is crucial to know which visual cue triggers an escape response. Previous work suggests that the cues that are most predictive of escape are the angle subtended on the eye by the edges of the approaching predator (θ) and its rate of change (θ '). We performed two sets of experiments to test which cues predict the timing of an escape response in adult zebrafish. The first experiment found threshold values for θ and θ that best predicted the timing of an escape response in response to a projected black circle that expanded at a variable rate. These results were consistent with a second set of experiments, which exposed fish to a live fish predator (Herichthys cyanoguttatus). This experimental series offers a strong behavioral basis for how zebrafish respond to approaching predators.

S11-7 MCKENNA, KZ*; NIJHOUT, HF; Duke University; *kzm@duke.edu*

Exploring the role of insulin signaling in relative growth: a case study on wing-body scaling in Lepidoptera

Adult forms emerge from the relative growth of the body and its parts. Each appendage and organ have a unique pattern of growth that influences the size and shape it attains. This produces adult size relationships referred to as static allometries, which have received a great amount of attention in evolutionary and developmental biology. However, many questions remain unanswered, e.g. What sorts of developmental processes coordinate growth? And how do these processes change given variation in body size? It has become increasingly clear that nutrition is one of the strongest influences on size relationships. In insects, nutrition acts via insulin/Tor signaling to facilitate inter- and intra-specific variation in body size and appendage size. Yet, the mechanism by which insulin signaling influences the scaling of growth remains unclear. Here we will discuss the potential roles of insulin signaling in wing-body scaling in Lepidoptera. We analyzed the growth of wings in animals reared on different diet qualities that induce a range of body sizes not normally present in our laboratory populations. By growing wings in tissue culture, we survey how perturbation or variation in insulin/Tor signaling influences cell growth and cell proliferation. To conclude, we will discuss the implications of our findings for the development and evolution of organismal form.

P2-276 MCKENNA, A/J*; SMITH, A; GIBBS, A/G; Univ. of Nevada, Las Vegas; *austin.mckenna@unlv.edu*
Rapid Evolution of Starvation Resistance in Drosophila: Physiological and Molecular Mechanisms
We subjected five replicate populations of *Drosophila melanogaster* to selection for starvation resistance and compared them to a founding control population that had been maintained at large population sizes to reduce linkage disequilibrium. After only one generation of selection, all five replicate selected populations survived longer without food than the control population, and starvation survival continued to increase over the next 9 subsequent generations. Previous studies have shown that long-term starvation-selected Drosophila contain more lipid, have lower metabolic rates and develop more slowly than controls. Lipid contents in our selected populations increased within three generations, and development tended to be slower within five. Samples were collected each generation for a genome-wide association study to link changes in SNP allele frequency with evolved phenotypic changes. Preliminary findings of the GWAS will be presented.

47-1 MCMAHAN, S*; BHANDAWAT, V; Duke University; *sbm37@duke.edu*
Contribution of biomechanics and neural activity in determining resting leg positions in Drosophila.
Limb size has a large effect on determining where it rests. A large limb's resting position is predominantly determined by gravitational forces. As a limb becomes smaller, it is progressively dominated by passive forces. All control systems have to deal with these material properties, but there are few measurements of these material properties in an intact animal. We take advantage of genetic tools in flies to measure how the passive properties of the limb and active control from motor neurons (MNs) work to determine the resting leg position. In this study, we measure the angle of the coxa and femur-tibia joints at rest during both active (MNs are active), and passive (MNs are genetically silenced by expressing the green-light inhibiting chanelrhodopsin, GtACR1 in motor neurons using VGlut promoter) stop positions. After reconstructing the passive and active leg stops in a 3D space we see two distinct clusters for the two types of stops. Using the passive limb configuration, we were able to measure the passive properties of each joint in the leg. The stop positions for passive and active stops were distinct, and indicate that the active stops are being controlled by MNs. To test this hypothesis, and to characterize whether the distinct stop position during active stops represent baseline MN activity, or whether there are dedicated MNs that control the joint position at rest, we will perform calcium imaging in the same experimental setup. Together, we will provide a quantitative description of the role that neural activity and passive forces play in the control of a fly's active resting leg position.

70-3 MCNAMARA, GPJ*; KIRCHER, ; COHN, ; University of Florida; *griffinmcnamara@ufl.edu*
Sexually dimorphic digit development in Anolis sagrei
Tetrapod digits are often characterized by sexually dimorphic digit proportions. For example, in male 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. In previous work, our lab demonstrated that differences in the relative levels of androgen and estrogen signaling during limb development underlie the sexually dimorphic 2D:4D ratios in mice. Sexually dimorphic digit ratios have been described in a number of mammals and in a few non-mammalian species, including frogs, lizards and birds; however, the developmental basis of these patterns has not been examined outside of mice. In this study, we investigated digit development in the iguanid lizard Anolis sagrei to determine whether sexually dimorphic digit development is conserved between mammals and squamates. We show that A. sagrei develops sexually dimorphic digit proportions, but the timing and pattern of dimorphic skeletal growth are strikingly different from development of digit dimorphisms in mammals.

P2-223 MCNEMEE, RE*; GREENWAY, R; TOBLER, M; Kansas State University; *remcnemee@ksu.edu*
Genital evolution in livebearing fishes of caves and toxic springs
Populations of *Poecilia mexicana*, a live-bearing fish common in freshwater streams in Southern Mexico, have adapted to life in toxic sulfide streams in and outside of caves. Previous studies have shown that these populations have evolved morphological, physiological, and behavioral adaptations to extreme environments, resulting in ecological speciation. Reproductive isolation between populations in differing habitat types is facilitated by natural and sexual selection against migrants between habitats. However, selection against migrants cannot solely explain the low levels of observed gene flow. We predict genital divergence between populations may contribute to reproductive isolation. The question remains, however, whether and how the genitalia of males (gonopodial tip) and females (urogenital aperture) differ among populations inhabiting contrasting environments. Particularly, the cave populations may have evolved differences in genital traits associated with a sensory role in sexual selection in the absence of light. We quantified genital variation in four populations of *Poecilia mexicana* (sulfide surface, non-sulfide surface, sulfide cave, and non-sulfide cave) with ongoing speciation to test if male and female genitalia diverge in a correlated fashion. We found that there is divergence in genitalia across populations in different habitat types. We also document evidence that male and female genitalia have coevolved within populations. The basic requirements for mechanical isolation are consequently fulfilled in this system, and experimental studies are now needed to understand the functional significance of genital variation.

P3-42 MCPEEK, S. J.*; KOTNOUR, J. L.; GLOVER, M.; MBUYU, N.; WRIGHT, N.; Kenyon College; *mcpeeks@kenyon.edu*

Searching for sexually dimorphic flight in Eastern bluebirds (Sialia sialis)

The presence and extent of sexual dimorphism is an important question in all aspects of the zoology of a species. Birds provide some of the most striking examples of this phenomenon, like the male Eastern bluebird's vibrant blue plumage compared to the female's dull periwinkle. However, investigations of sexual dimorphism are traditionally limited to physiological differences such as body size, color, and secondary sexual traits, with little focus on whether sex differences could affect behavioral traits such as flight performance. We used high speed video footage of flight from 10 breeding pairs of Eastern bluebirds in rural Ohio to ask whether males and females exhibit sexual differences in their flight behaviors during the breeding season. We hypothesized that females have impaired flight performance during the breeding season compared to males due to the higher energetic costs of reproduction on females. Our findings suggest that males and females exhibit sexual differences in their flight behaviors during reproduction. These results imply that sexual dimorphism in birds extends to complex behavioral traits, and further work should address how these differences manifest during the non-breeding season.

P2-60 MCPHERSON, DR; SUNY Geneseo, New York; *mcpherso@geneseo.edu*

Retrograde labeling of neuronal projections to the heart in the pond snail, Lymnaea stagnalis

As in vertebrates, the heart of gastropod mollusks is myogenic with neuromodulation from the central nervous system. In the pond snail Lymnaea stagnalis the primary source of neuromodulation is by way of the intestinal nerve. Earlier explorations of the central nervous system have identified several populations of neurons that have recognizable modulatory effects on heart rate and cardiac muscle contraction, but it is not certain that all of the relevant neurons have been identified. To address this, I have carried out backfills of the intestinal nerve using using biocytin, which yields backfills of superior quality. The results indicate a much larger and more widespread innervation of the heart than has been previously described. A portion of the newly observed neurons may be sensory, while others may have motor effects. The results will be compared to previous results and the identity of possible transmitters will be explored by double-labeling using transmitter-specific antibodies.

P1-87 MCTERNAN, MR*; SEARS, MW; ANDERSON, RA; Clemson University, West. Wash. University; *mmctern@g.clemson.edu*

Higher Food Availability May Offset Energetic Limitations Associated With Less Activity Time

Warming climates are projected to shift the activity patterns of many animals. While animals with longer periods of activity have a higher potential for somatic growth, some locally adapted populations may deviate from this expectation. We studied two populations of *Sceloporus occidentalis* in Washington State, one in a cool climate and one in a warm climate. The cooler climate restricts activity, yet individuals from this population still reach a fatter body condition. Individuals from the cool site also expend more energy daily on maintenance metabolism but have higher food availability. As such, we hypothesize that higher food availability at the cool site may permit greater seasonal maintenance energy expenditure that still results in more residual energy left for storage. To evaluate our hypothesis, we use estimates of activity time and measures of maintenance metabolism to calculate seasonal maintenance energy expenditure. We then subtract these values from seasonal daily energy intake estimates to calculate residual energy supply. While activity patterns of many animals are expected to shift with warming climates, food availability may play a key role in offsetting potential energetic consequences.

98-7 MCWILLIAMS, S.*; PIERCE, B.; WITENZELLNER, A.; LANGLOIS, L.; SPEAKMAN, J.; DEMORANVILLE, K.; GOYMANN, W.; TROST, L.; BRYLA, A.; DZIALO, M.; SADOWSKA, E.; BAUCHINGER, U.; University of Rhode Island, Sacred Heart University, Max Planck Institute for Ornithology, Chinese Academy of Sciences, Max Planck Institute for Ornithology, Jagellonian University; *srmcwilliams@uri.edu*

The energy savings-oxidative cost tradeoff for birds during migration

Elite athletes must eat well so that they acquire the fuels necessary for extreme feats but also so they can contend with the oxidative costs and potential damage associated with peak metabolic performance. Here we show that the energy cost of long-duration flights for a migratory bird is related to the fatty acid composition of fat stores; however, this fat-mediated energy savings during long flight requires birds to contend with increased oxidative damage over the long-term. We used diet manipulations to produce starlings with adipose stores that differed in the relative amounts of certain mono- and polyunsaturated fats (MUFA versus PUFA). These starlings were then flight-trained and successfully flew non-stop for 6 hrs in a windtunnel during which we measured energy expenditure using the doubly-labelled water technique. Starlings with fat stores composed of relatively more of an essential omega-6 PUFA expended 11% less energy during these 6-hr flights than starlings composed of relatively more MUFA; however, this came at an apparent long-term cost in that the omega-6 PUFA-fed birds incurred significantly higher oxidative damage. Our study provides compelling evidence that avian athletes face a considerable tradeoff when deciding what to eat to enhance their performance. This may explain why migratory songbirds carefully discriminate between diets that differ only in their fatty acid composition, and consistently choose a specific ration of 18:2 to 18:1 because it may optimize the energy savings-oxidative cost tradeoff. Supported by NSF (IOS-0748349 to S.R.M. and B.J.P.) and NSC Poland (2015/19/B/NZ8/01394 to U.B.)

P2-155 MECKEL, S; LADNER, R; WILLIAMS, JB*; Southern Illinois University Edwardsville; *jasowil@siue.edu*

Diurnal temperature variation enhances survival and potential fecundity in the overwintering goldenrod gall fly, Eurosta solidaginis

Previous work suggests elevated winter temperature speeds the onset of post-winter development as well as negatively impacting survival and potential fecundity. However, these studies typically used constant exposure temperature with less consideration of the potentially important contribution of diurnal variation. To determine the effect of variable winter temperature on the above parameters, we compared pupation date, survival, and potential fecundity in the goldenrod gall fly, *Eurosta solidaginis*, exposed to constant, average monthly temperature or diurnal cycles that fluctuated between monthly low and high temperature (average-constant or average-variable groups). In addition, to assess the effect of elevated winter temperature we subjected larvae to constant temperature and a diurnally fluctuating regime as predicted by a climate change model (elevated-constant or elevated-variable treatment). Elevated winter temperature sped development as larvae exposed to constant, elevated temperature had a median date of pupation of March 24, which occurred 13, 24, and 36 days before those in the elevated-variable, average-variable, or average-constant treatments respectively. Levels of adults displaying a righting response five days after eclosion was greatest in those subjected to the elevated-variable treatment (54%), while the remaining groups averaged only 30%. Exposure to variable winter temperature preserved potential fecundity as females in the elevated-variable and constant variable treatments produced and average of 148 ± 14 eggs compared to just 104 ± 9 eggs in the constant temperature treatments. In sum, elevated winter temperature sped the onset of spring development, while variable temperature regimes enhanced survival and potential fecundity.

13-1 MEKDARA, PJ*; SCHWALBE, MAB; TYTELL, ED; Tufts University, Lake Forest College; *prasong.mekdara@tufts.edu*

Tail synchronization of schooling giant danios is altered after lateral line system ablation and regeneration

Schooling fish use multiple sensory systems to maintain position and speed within a school, and disabling their flow sensing lateral line system is known to alter schooling behavior. The lateral line contains two parts: an anterior portion that is affected mostly by oncoming flow as the fish swims forward, and a posterior portion that is more affected by the side-to-side swimming movement. Therefore, the two portions may have different roles in maintaining behaviors, including schooling, navigating around complex obstacles, foraging, mating, and predator detection. In this study, we examined schooling behavior in fish immediately after we ablated only their anterior lateral line, only the posterior, or the complete lateral line systems, and we tracked the behavior at weekly intervals after the system regenerated. We filmed schools of five giant danios, *Devario aequipinnatus*, with two high-speed cameras and reconstructed the 3D positions of each fish within a school. We found that fish with any of the three ablation treatments were able to maintain a normal position within the school immediately after treatment. However, fish with their anterior or entire lateral line system ablated could not school normally one and two weeks after treatment, even though the hair cells regenerated, but those with the posterior lateral line ablated were able to school normally. Within the school, control fish generally synchronize tail beats. Immediately after treatment, all fish have difficulty maintaining tail beat synchrony. The effect persists for much longer for fish with the posterior lateral line ablation, compared with those that have the anterior ablation. By four weeks post-treatment, all treated fish could again school normally. These results indicate that the anterior and posterior lateral line serve different functional purposes during schooling.

21-4 MELICHER, DM*; YOCUM, GD; TORSON, AS; RINEHART, JP; United States Department of Agriculture, Agricultural Research Service, University of Western Ontario; *dacotah.melicher@ars.usda.gov*

Immediate transcriptional response of Megachile rotundata to a temperature pulse under a fluctuating thermal regime

Insects demonstrate a remarkable ability to tolerate a broad range of internal temperatures caused by daily thermoperiod and seasonal variation in ecological conditions. Fluctuating thermal regimes (FTR) have been shown to extend longevity and reduce mortality under long-term cold storage for multiple insect species by allowing recovery from accumulated chill injury. Under FTR the Alfalfa leafcutting bee, *Megachile rotundata* are maintained at 6°C with a daily warm pulse lasting one hour at 20°C with one hour ramping up and down. We profile the short-term transcriptional response of *M. rotundata* to FTR by sequencing bees sampled before, during, and after the warm pulse, compared to those held at Constant Low Temperature (CLT). We identify differentially expressed genes, enriched functional classes of proteins, and pathways that respond to the warm pulse and identify genes that may be associated with the protective effects of FTR. Specifically we focus on those associated with oxidative stress response, cell membrane and membrane-bound proteins, and restoration of ion balance and contrast short-term versus long-term response to chill injury.

P1-277 MELSTROM, KM*; WISTORT, ZP; University of Utah; *keeganmelstrom@gmail.com*

Quantification conundrum: Just how repeatable are dental complexity measurement methods?

Increases in the availability and affordability of 3D model generation have led to the rapid development of methods that evaluate the morphology of extinct and extant animals. In particular, orientation patch count rotated, a technique that quantifies phenotypic tooth morphology, allows for the direct comparison of dental elements without homologous landmarks. This method has been particularly useful in the ecological reconstructions of extinct taxa. Given the fast pace of technological development, the program that initially developed the method, Surfer Manipulator, is often not used in subsequent studies, replaced by more intuitive, flexible, or freely available programs. Unfortunately, the repeatability of these methods is neglected due to a combination of factors including dissimilar datasets or unavailability of programs. Here, we use a single dataset of saurian teeth to directly test the compatibility of three orientation patch count rotated methods: Surfer Manipulator, the R-package 'molaR', and MorphoTester. We find that the freely available programs, MorphoTester and molaR, consistently produce identical dental complexities, an expected observation as these programs calculate dental complexity in the same fashion. In contrast, these programs do not replicate the measurements generated from Surfer Manipulator, frequently producing higher average dental complexity values. In particular, dentitions belonging to carnivores are especially susceptible to this disparity. We strongly recommend that datasets created from combinations of these methods should not be used, especially for ecological reconstructions. These results emphasize the importance of replicating previous studies with the advent of novel methods. Additionally, in the case of orientation patch count rotated, care needs to be taken when deciding what method to apply to one's dataset.

35-6 MENARD, SS*; WATSON, GM; University of North Carolina at Charlotte, University of Louisiana at Lafayette, University of Louisiana at Lafayette; *menard.shelcie@gmail.com*

Epithelial Effects of Exposure to Streptomycin on the Tentacles of the Sea Anemone, Nematostella vectensis

Aminoglycoside antibiotics, such as streptomycin, cause ototoxic effects in vertebrate animals, but damage to hair cells caused by long-term exposure to aminoglycosides has not been studied in invertebrate animals. This study investigated the effects of streptomycin on the tentacle epithelium of the sea anemone, *Nematostella vectensis*. The number of hair bundles located at the bases of tentacles of sea anemones significantly decreased in response to streptomycin exposure. There was also a significant reduction in the number of mitochondria (labeled with MitoTracker) in response to streptomycin exposure, at both the tips and bases of tentacles. Within 1 hour of streptomycin exposure, there was a significant increase in the number of nuclei that had been labeled with EdU, a thymidine analog. Within 4 hours of streptomycin exposure, there was a significant increase in the number of nuclei that had been labeled with Hoechst, a DNA stain. Together, the EdU and Hoechst labeling results indicate an increase in cell proliferation, possibly intended to replace hair cells killed by streptomycin. These findings indicate that long-term exposure to streptomycin is destructive to the tentacle epithelium of sea anemones.

42-2 MENDOZA, E*; AZIZI, E; MOEN, DS; Oklahoma State University, University of California, Irvine; *emendoz7@uci.edu*

The Diversity and Evolution of Jumping Power in Anurans

Jumping in anurans requires substantial mechanical power. However, while muscle power appears to be relatively invariant across species, jumping power is highly variable. Power amplification using stored elastic energy is thought to explain this discrepancy. However, the interspecific variation in the propensity to amplify power remains poorly understood. One possibility is that differences in intrinsic muscle properties due to size may limit the amount of power a muscle can generate, leading to small species needing greater amplification than larger species. Alternatively, the microhabitat species inhabit may drive the variation. In this study, we used high-speed video to record jumping for 23 anuran species. Additionally, we included unpublished jumping power data for one species and jumping power data for 44 species from a previous study. Species were diverse in microhabitat use and body mass, and they came from across the phylogeny of all anurans. We used phylogenetic comparative methods to compare the role of microhabitat and body mass in explaining variation in power amplification across species. We found the strongest support for a model that included both body mass and a microhabitat category that classified species as either burrowing or not. The effect of body mass suggests that interspecific variation in jumping power might be partly explained by intrinsic limitations of muscle. Anurans with small body mass may be able to achieve similar locomotor performance (e.g. take-off velocity) as those with larger body mass, but only by more effectively amplifying power. Additionally, the effect of microhabitat suggests that organisms that use the same limbs for both jumping and burrowing may experience a reduction in their ability generate jumping power. This may indicate a functional trade-off between jumping and burrowing.

92-2 MERESMAN, Y*; HUSAK, JF; BEN-SHLOMO, R; RIBAK, G; Tel-Aviv Univ., Israel, Univ. of St. Thomas, St. Paul, MN, Univ. of Haifa - Oranim, Tivon, Israel; *meresman@post.tau.ac.il*

The Effect of Variation in Hindwing Morphology on Elastic Wing Deformation During Free-Flight in Scarab-Beetles

Insects demonstrate a broad diversity of wing morphology and different flight styles demanded by their environment. Among other things, the wing-vein arrangement determines the structural properties of the wing and therefore affects how a wing elastically deforms during flapping flight in a manner that may be species specific. Since insects lack intrinsic wing muscles, the wing's elastic deformability may be important for fine tuning the aerodynamic performance of the wings of insects adapted for different flight styles. The relationship between the arrangement of specific wing veins, wing deformability and the adaptation of insect-wings for various flight styles are poorly understood. We examined the wing vein arrangement of 20 scarab-beetle species (Coleoptera: Scarabaeidae) differing in ecology and flight style using geometric morphometric analyses corrected for phylogenetic relatedness. Wing deformations during free-flight were directly compared between flower-chafers (*Protaetia cuprea*) and dung-beetles (*Scarabaeus puncticollis*), representing two extremes in ecology and divergence of wing vein morphology. Sub-families within the Scarabaeidae primarily differed in the vein arrangement at the distal leading-edge and at the proximal trailing-edge of the wing. Despite similar flapping kinematics, flower-chafer wings displayed larger deformation and different distribution of the deformation compared to the dung-beetles. These inter-species differences in the deformation magnitude and distribution could lead to different flight performance that matches environmental demands.

S2-4 MERRILL, L*; BARGER, AM; BENSON, TJ; University of Illinois, Urbana-Champaign; *loren21@illinois.edu*

Landscape dynamics and immune function across a community of shrubland birds

Disease dynamics in wild organisms depend upon a suite of intrinsic and extrinsic factors including host competence and immunocompetence, host community dynamics, and environmental composition. There is good data on disease risk varying across the landscape, but generally less information on whether and how host immune defenses vary across the landscape. Furthermore, there is strong empirical evidence that developing individuals of most species have reduced immune function compared to adults, but other than a broad trend for individuals raised in more resource-rich environments having stronger parasite defenses, we have little data on how immune function varies across the landscape in immature organisms. In this study we examined aspects of immune function in adults and nestlings of five bird species that co-occur in shrublands in the Midwest US with relatively similar life-histories. In addition to assessing interspecific variation and the relative values of nestlings compared to the adults, we examined whether immune function covaried with proportion of four different land-cover types at different spatial scales around the nest. We found interspecific variation in immune function as well as substantial differences in nestling immunological investment relative to adults. Furthermore, we documented covariance between some immune components and proportion of land-cover types, although this varied by species and age class. Our results highlight the importance of examining variation in immune function across the landscape, and in considering variation between nestlings and adults when assessing competence levels for a given species.

99-6 MESA CRUZ, B*; RHOADS, R; ZHAO, L; KROSCHER, K; BROWN, J; KELLY, M; Elizabethtown College and Virginia Tech, Virginia Tech, Smithsonian Institution; *mesab@etown.edu*

Skeletal Satellite Cell Myogenic Activity in Hibernating American Black Bears

Bears are able to limit muscle atrophy during hibernation, a period of low metabolic rates, decreased physical activity, anorexia, and adipsia. Even though skeletal muscle function and architecture is regulated through multiple physiological pathways, the role of satellite cells (SCs), and their endocrine signaling, in hibernating species remain understudied. We aimed to elucidate *in vitro* SC proliferation and differentiation associated with physical movement and serum myostatin in the American black bear (ABB) (*Ursus americanus*) during fall hyperphagia, hibernation, and spring activity. We performed muscle biopsies and collected sera from adult males and females (n= 2 and 4, respectively) at Virginia Tech's Black Bear Research Center. Our results show that: 1) SCs maintain their ability to proliferate *in vitro* at similar rates throughout all ABB metabolic states, including hibernation, 2) *in vitro* SC differentiation and myogenic ability is increased during ABB hibernation, coinciding with a decrease in circulating serum myostatin, and 3) there are dramatically different nuclei fusion rates (i.e., differentiation) between males and females with cubs post hibernation, suggesting that reproductive females face additional metabolic constraints during spring arousal in order to maintain the integrity of skeletal muscle. We propose that maintaining the SC proliferative and differentiation abilities during hibernation is an important potential pathway for limiting muscle atrophy during bear hibernation. Functional aspects of bear muscle conservation are interesting for understanding bear physiological adaptations to hibernation and also potentially for elucidating avenues to improve treatments for human muscular disorders.

P2-94 MEYER, SC*; JOHNSON, CA; PINTOR, LM; Georgia Southern Univ., Ohio State Univ., Ohio State Univ; *sm30152@georgiasouthern.edu*

Giving Up Density as an Approach to Identify a Difference in Foraging Behavior Between Native and Invasive Crayfish Species

Orconectes rusticus is a prolific invasive crayfish species that has invaded a broad geographic range and has displaced several crayfish species. Previous studies have investigated the differences in life stages and physical characteristics of *Orconectes sanbornii* and *Orconectes rusticus* but did not include individual foraging behavior in their comparisons. A better understanding of the behavior of *O. rusticus* is needed to understand why it is such a successful invader. In Ohio streams *O. rusticus* has been displacing *O. sanbornii* in a major portion of its natural range. Here we tested whether native *O. sanbornii* were displaced by invasive *O. rusticus* through superior foraging and whether foraging behavior changed in the presence of a model fish predator. We used depletable food patches of chicken liver to compare the foraging behavior of native *O. sanbornii* and invasive and native populations of *O. rusticus* under high, low or no predation risk. We then measured the remaining food concentrations in each patch after a 24-hour period as an indication of giving up density (GUD). We found that there was no significant effect of predation risk on the GUD of either species. However, *O. sanbornii* left significantly lower GUDs on average than either native or invasive populations of *O. rusticus*. Which suggests that *O. sanbornii* is a more active forager than *O. rusticus*. Our research indicates that the invasion mechanism that *O. rusticus* employs to displace *O. sanbornii* is not exploitative foraging but rather an unidentified mechanism. Gaining a better understanding and being able to better identify the mechanisms of species invasions can lead to better and more effective management of invasive species in the future.

CXL-0 MEYER, K.S.; PITTOORS, N.C.*; MULLINEAUX, L.S.; Woods Hole Oceanographic Institution, Northern Michigan University; *npittoors@gmail.com*

Interactive effects of temperature and biotic interactions influence succession in subtidal fouling communities

Fouling communities are excellent model systems for answering fundamental questions in ecology. They are easily accessible and provide the opportunity for detailed manipulative experiments. A major unanswered question in ecology is what mechanisms drive succession. Many studies have described how communities change and develop over time, but very little is known about the underlying reasons why. We studied the mechanisms of succession in invertebrate fouling communities in New England in order to understand (1) how local water temperature influences the first species to recruit to a substratum and (2) how interspecific interactions shape the community over time. Our results reveal significant differences in recruitment and community composition at two sites < 1 km apart, but with consistently different water temperatures. At each site, the first species to dominate the community (the hydroid *Ectopleura crocea* and the ascidian *Botryllus schlosseri*, respectively) inhibited the recruitment of some taxa but facilitated the recruitment of others. Both dominant species also degenerated when water temperature exceeded their tolerance limits at their respective sites, creating space for colonization by other taxa. Our study demonstrates that multiple mechanisms of succession (facilitation, inhibition) may be at work in a single community, and that interactive effects of local environmental conditions and biotic interactions influence succession. Many fouling species are non-native to their respective habitats. Our study shows that in order to understand how these species become established in new environments, both abiotic and biotic factors, as well as interactions of these factors, must be taken into consideration.

48-4 MHATRE, N*; MALKIN, R; DEB, R; BALAKRISHNAN, R; ROBERT, D; University of Toronto, University of Bristol, Indian Institute of Science, Bangalore, Indian Institute of Science, Bangalore; *natasha.mhatre@gmail.com*

Tree Crickets can make Optimal Tools

Tree crickets are members of a very small group of insects who are known to manufacture a tool. They use this tool, called a baffle to increase the loudness of their mating calls. Here we show that tree crickets can optimize this tool. Using finite element modelling we quantified the efficiencies of baffles of different designs and found that design has a strong influence on tool efficiency. We then conducted a series of experiments which tested whether the crickets chose the best material for making the tool, and whether they modified it to make it acoustically optimal. Indeed, given the opportunity, tree crickets could made an optimal tool. Our analysis suggests that both tree cricket tool manufacture and optimization are based on a simple behavioural heuristic that is likely to be inherited. Thus our data suggests that the flexibility required for tool optimization can be achieved by a simple and heritable behavioural programme.

76-2 MICHAELIS, B. T.*; REIDENBACH, M.; University of Virginia; *brenden.t.michaelis@gmail.com*

Smelling time: using temporal variability in chemical cues to aid odor-mediated search by lobsters

Animals often use their sense of smell to locate food, identify mates and predators, and find suitable living habitats. Odor molecules are dispersed from their source by turbulent wind or water currents. In both terrestrial and aquatic environments, the instantaneous temporal and spatial distribution of odors is complex, and odor plumes are often composed of filaments of chemicals at high concentrations that are adjacent to fluid with little or no odor. Navigation in turbulent chemical plumes has typically been considered a spatial information problem where individuals aim to path towards higher concentration. However, concentration information alone is too irregular in turbulent plumes to explain search speed and accuracy of many animals that undergo search. Recent discoveries of bursting olfactory neurons in the spiny lobster, *Panulirus argus*, suggest a mechanism for accurately sampling the temporal structure of chemical signals. We believe that incorporating a temporal element to chemical cues, such as intermittency encoding, is necessary to provide plume information on time scales relevant for informing efficient search behavior. We use a computational fluid dynamics model, as well as full-scale flume experiments using planar induced fluorescence, to characterize the spatial-temporal signal encountered in a turbulent odorant plume.

P3-61 MICHEL, K B*; WEST, T G; DALEY, M A; ALLEN, V; HUTCHINSON, J R; Royal Vet College, London; *kmichel@rvc.ac.uk*

A comparison of appendicular muscle physiology and biomechanics in Archosauria

Archosaurian reptiles (including living crocodiles and birds) have had an explosion of locomotor variation since the Triassic. Their appendicular muscle physiology and biomechanics are pivotal to our understanding of how their diversity, natural history and evolution relate to this locomotor variation. Information on muscle contraction velocity, force and power in extinct archosaurs such as Pseudosuchia and Ornithodira is of course not available from fossil material, but is needed for biomechanical modelling and simulation. However, an approximation or range of potential parameter values can be obtained by studying extant representatives of the archosaur lineage. Here, we perform a quantitative study of the physiological performance of multiple muscles from several individuals of Nile crocodile (*Crocodylus niloticus*) and Elegant crested tinamou (*Eudromia elegans*). Nile crocodile musculature shows high power and velocity values-- the FTI4, a small "hamstring" hip extensor and knee flexor actively used for terrestrial locomotion, performs particularly well. The Elegant crested tinamou muscles' performance is on par with birds of similar body mass, and shows the same pattern of parameter variation between muscles of a similar function in other birds. These findings demonstrate physiological differences between anatomical muscles, potentially based on their roles during locomotion. By contributing new data from previously unstudied archosaurian species and muscles to existing data, we can now better bracket possible muscle parameter values, and thereby better estimate in computational analyses how extinct archosaurs may have moved.

P2-184 MIDKIFF, B.S.*; DEAROLF, J.L.; THOMETZ, N.M.; Hendrix College, Conway, AR, Univ. of San Francisco, CA; *midkiffbb@hendrix.edu*

Comparison of glycolytic metabolism in bottlenose dolphin and harbor porpoise vocal muscles

Toothed whales use a specialized nasal system to produce vocalizations that they use to navigate and communicate. For example, the Atlantic bottlenose dolphin (*Tursiops truncatus*) uses its primarily slow-twitch left nasal musculature (LNM) to produce whistles, while its right nasal musculature (RNM) produces clicks using fast-twitch fibers. In comparison, the harbor porpoise (*Phocoena phocoena*) only emits clicks, and its LNM and RNM are both primarily fast-twitch. Thus, we hypothesized that the dolphin RNM would have higher glycolytic activity than its LNM and both porpoise musculatures would have similar glycolytic activities. To test these hypotheses, samples of the LNM and RNM of dolphins and porpoises were collected from stranded animals and frozen. The muscle samples were prepared for the lactate dehydrogenase (LDH) assay, and their LDH activities were assayed under the following conditions: 50 mM imidazole, 0.15 mM NADH, 1 mM pyruvate, and pH 7.0 at 37oC. Using a microplate reader, we measured the rate of change in absorbance (340 nm) at Vmax to calculate glycolytic activity. One specimen per muscle of each species was used to determine the optimum dilution factor before running that dilution factor on all specimens. *T. truncatus* RNM glycolytic activity was found to be 207.4 (± 95.2) µmol /min*g, while the LNM activity was 172.9 (± 12.6) µmol /min*g. *P. phocoena* equivalents were 266.9 (± 205.4) and 215.7 (± 105.7) µmol /min*g. Results showed higher glycolytic activity in the RNM than in the LNM for both species and higher glycolytic activity in porpoise muscles compared to the dolphin equivalents. However, all four of the measured glycolytic enzyme activities were low, which fits with the small energy requirements of clicking in these cetaceans.

121-3 MIKUCKI, EE*; LOCKWOOD, BL; University of Vermont; *emikucki@uvm.edu*

Winter warming threatens cold tolerance and survival in diapausing Pieris rapae butterflies

Temperate species of insects are annually tasked with surviving the winter. Diapause allows these insects to survive harsh winter conditions. Diapause is a state of physiological dormancy characterized by decreased metabolic activity, developmental arrest, and heightened environmental stress and cold tolerance. To date, the environmental, hormonal, and genetic regulators of diapause have been well-described and characterized. However, since diapause is a complex program dependent on seasonal timing and temperature, increases in extreme climatic events have the potential to negatively alter these processes, potentially leading to increased mortality in diapausing individuals. To better understand the effects of winter warming on diapause physiology, diapausing *Pieris rapae* butterfly pupae were exposed to short and long-term warming events, mimicking those of concurrent and predicted climate patterns. Our results show that diapausing pupae exposed to short and long-term warming events had compromised cold tolerance levels (higher internal freezing temperatures) relative to control individuals not exposed to the warming events. Additionally, warmed individuals experienced faster developmental timing, and lowered eclosion success. Furthermore, results from global metabolomics assays suggest that biochemical traits important to diapause regulation and maintenance can also be affected by winter warming patterns. These results suggest that continued winter warming patterns will pose physiological challenges to overwintering temperate species that rely on diapause.

101-2 MILANI, L*; GHISELLI, F; University of Bologna, Italy; *fabrizio.ghiselli@unibo.it*

Natural heteroplasmy, mitochondrial inheritance and activity in bivalve molluscs

Heteroplasmy is the presence of more than one type of mitochondrial genome within an individual, a condition commonly reported as unfavourable and affecting mitonuclear interactions. So far, no study has investigated heteroplasmy at the protein level, and whether it occurs within tissues, cells, or organelles. The only known evolutionarily stable and natural heteroplasmic system in Metazoa is the Doubly Uniparental Inheritance (DUI), reported so far in ~100 bivalve species, in which two mitochondrial lineages are present: one transmitted through eggs (F-type) and the other through sperm (M-type). Because of such segregation, the mitochondrial OXPHOS proteins reach a high sequence divergence (up to 52%) between the two lineages in the same species. Gamete homoplasmy allows to compare the biochemical activity and the evolutionary features of the two sex-linked variants, and the high sequence divergence between F- and M-type proteins provides a unique opportunity to study their expression and assess level and extent of heteroplasmy. Immunolocalization showed heteroplasmy at the organelle level in undifferentiated germ cells of both sexes, and in male soma. Thus, during gametogenesis only the sex-specific mitochondrial variant is maintained, possibly due to meiotic drive and/or selection of a specific phenotype (such as membrane potential or membrane tag). Molecular and phylogenetic evidence suggests that DUI evolved from the common strictly maternal inheritance, so the two systems share the same underlying molecular mechanism, making DUI a useful system for studying mitochondrial biology.

P1-64 MILLER, AL*; HEARST, LW; University of Tampa; *abraham.miller@ut.edu*

Evolution of Relative Eye Size in Scorpions

The evolution of eye size has been studied across multiple vertebrate and invertebrate taxa. Most research has focused on species with high visual acuity or the adaptive loss of eyes in no light environments. In scorpions, the eyes have been studied to assess their sensitivity and function. However, little attention has been given to the evolution of eye size in scorpions, with the exception of troglobite species. 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. We previously found that relative median eye size, was significantly larger in a species from Florida (high canopy cover), than in a species from the western US (low canopy cover). This research tested the relative size of the median eyes, in multiple species of scorpion, across multiple families and environments. It was predicted that species from greater canopy cover would exhibit larger relative eye size, and differences would be greater among families than within. 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. These data coupled with phylogenetic analysis could give great insight into our understanding of the evolution of eye size.

139-5 MILLER, L. A.*; BATTISTA, N.; OZALP, K.; University of North Carolina, College of New Jersey; *lam9@unc.edu*

Fluid transport and mixing in tubular insect hearts

Valveless, tubular pumps are widespread in the animal kingdom. For example, insect hearts are typically long narrow tubes that drive blood using a peristaltic-like waves. In this study, we use the immersed boundary method to simulate flow in a tube using a sinusoidal wave form. Simulations are performed in both two- and three-dimensions using parameters within the range of those observed for insects such as beetles, flies, mosquitoes, and moths. We quantify the relationships between fluid flow, compression frequency, compression wave speed, and tube occlusion in long narrow heart tubes typical of insects.Our results show that fluid flow speeds produced by peristalsis are greater than the speeds of the compression wave if the occlusion is sufficiently high; fluid flow is pulsatile; flow direction may temporarily reverse even when contractions are unidirectional; and flow speed has a nonlinear relationship with compression frequency when compression wave speed is held constant.

44-6 MILLS, KK*; BOWLING, BC; GUNDERSON, AM; OLSON, LE; University of Alaska Museum, University of Alaska Fairbanks; *kkmills@alaska.edu*

Why Are Some Marmots Black? The Genetics and Persistence of a Seemingly Harmful Trait in the North American Marmots

The hoary marmot (*Marmota caligata*) has a broad distribution in North America, but melanistic (black) morphs are known only in and around Glacier Bay National Park in SE Alaska. The adaptive role of melanism in hoary marmots is unknown. Melanistic marmots are more visually conspicuous than their wildtype counterparts, and we hypothesize they are more vulnerable to predation. However, black pelage may offer a thermoregulatory benefit as it should absorb more heat and reduce the need to sunbathe. Further, hairs dense with melanin may better resist microbial degradation, as the pigment melanin is known to confer microbial resistance. To explain the adaptive significance of melanism in hoary marmots, we first sought to explain the genetic underpinnings of the trait. We have collected six melanistic and two wild-type hoary marmots from the Chilkat Mountains outside Glacier Bay, collecting RNA-quality skin punches from each pelage color present on each marmot. I will present preliminary DNA sequence data of genes known to control pelage color in mammals from these individuals, as well as qPCR results demonstrating how these genes are expressed in skin growing hairs of different color. These will be compared to the same sequences from the hoary marmot's closest living relative, the critically endangered Vancouver Island marmot (*M. vancouverensis*), which is completely fixed for melanism over most of its body. I will also present scanning electron micrographs of individual marmot hairs of each color, which we examined for evidence of differential microbial degradation using methods from human hair forensics.

P1-135 MINER, KA*; GABOR, CR; Texas State University; *krystieaminer@gmail.com*

Physiology, Behavior and Reproductive Success of (Gambusia affinis) Under Artificial Light at Night

Artificial light at night (ALAN) is light that alters the natural light and dark cycle in an ecosystem and includes streetlights, headlights and flood lights. An estimated two-thirds of the world population is living in areas above the light pollution threshold. ALAN is known to have detrimental effects on wildlife by altering reproduction, foraging, predation, physiology, and orientation in multiple taxa. We used (*Gambusia affinis*), a widespread live-bearing fish, to study the effects of ALAN by exposing female fish to a constant light cycle and comparing cortisol, reproductive success, behavior and growth to those kept under a natural light cycle. We predicted that fish exposed to ALAN would have increased cortisol levels and activity compared to fish kept under a normal light cycle. We measured cortisol release rates five times over 60 days using a water-borne collection method. Cortisol is the primary glucocorticoid in fish and is indicative of an organism's physiological response to disturbance, therefore is an important parameter to measure when looking at anthropogenic influences such as ALAN. Under chronic stress cortisol may become permanently elevated or depressed and could suppress growth and reproduction. To examine this, we measured the stress response to agitation on day 60. We also explored the number and condition of broods from fish exposed to ALAN versus those in the control treatment. Results demonstrate that female (*G. affinis*) exposed to ALAN have lower mass compared to those in the control treatment.

103-5 MING, TY; SONG, JL; JIN, BW; LUO, HX; DU, RX; DING, Y*; Beijing Computational Science Research Center, Beijing, China, Department of Mechanical Engineering, Vanderbilt University, Nashville, TN, USA, Department of Mechanical and Automation Engineering, Chinese University of Hong Kong, Hong Kong SAR, China ; *dingyang@csrc.ac.cn*

How Fish Power Swimming -- a 3D Computational Fluid Dynamics Study

In undulatory swimming of fish, muscles contract sequentially along the body to generate a bending wave that pushes against the water and produces thrust. Here, we use a 3D computational fluid dynamics model coupled to the motion of the fish with prescribed deformation to study the force, torque, and power distributions along the fish's body. We find that forces on the bodies of both the anguilliform swimmer and the carangiform swimmer are dominated by reactive forces; furthermore, the force on the caudal fin of the carangiform swimmer is dominated by drag-like forces. The torque exhibits a wave pattern that travels faster than the curvature wave in both the anguilliform and carangiform swimmers, but the wave speed is higher for the carangiform swimmer. The power output for the anguilliform swimmer is concentrated on the anterior half of the body and is significantly negative on the posterior side of the body. In contrast, most of the power is generated by the posterior part of the body before the peduncle for the carangiform swimmer. The results explain the differences in the observed electromyography patterns in fish with different swimming modes and explain the tendon function in carangiform swimmers.

120-4 MINICOZZI, M.*; VON HIPPEL, F. A.; FURIN, C.; BUCK, C. L.; Northern Arizona University, University of Alaska Anchorage; *Michael.Minicozzi@nau.edu*

Sodium Perchlorate Induces Non-Alcoholic Fatty Liver Disease in the Developing Stickleback Liver

Perchlorate is a pervasive, water-soluble contaminant that competitively inhibits the sodium/iodide symporter, reducing the available iodine for thyroid hormone synthesis. Insufficient iodide uptake can lead to hypothyroidism and metabolic syndromes. Because metabolism, obesity and non-alcoholic fatty liver disease (NAFLD) are tightly linked, we hypothesized that perchlorate would act as an obesogen and cause NAFLD by causing the accumulation of lipids in developing threespine stickleback liver. We performed an upshift/downshift exposure regime (clean water to perchlorate exposed water or perchlorate exposed water to clean water) on stickleback embryos at three concentrations (0 mg/L, 30 mg/L and 100mg/L) over the course of 305 days. Adult stickleback were euthanized, collected for histology, H&E stained and analyzed for their liver morphology. Specifically, we counted the number of lipid droplets, measured the area of each droplet and the total lipid area of a representative section of liver. We found that perchlorate treated fish showed greater numbers of lipid droplets, larger lipid droplets and had a larger percentage of lipid in their liver than control fish. These data indicate that perchlorate is causing NAFLD and hepatic steatosis in stickleback at concentrations commonly found at contaminated sites. These data also indicate the potential of perchlorate to act as an obesogen. Future studies should investigate the obeseogenic capacity of perchlorate by examining organ specific lipid accumulation. Work is also needed to determine the mechanisms by which perchlorate induces lipid accumulation.

P1-265 MINSKY, G*; GOODHEART, J; GONZALEZ, M; MUñOZ, D; TORRES, E; OAKLEY, T; UCSB; *ggminsky@ucsb.edu*

Developing The California Sea Firefly (Vargula tsujii) as a laboratory organism to study the genetic basis of species diversification by sexual selection

Sexual selection may lead to increased diversification of species, as exemplified by origins of luminous courtship in multiple animal groups, including cypridinid ostracods (Crustacea). Dozens of species of cypridinids radiated in the Caribbean using a wide range of luminous courtship displays. Although the biochemistry and genetics of bioluminescence are well studied, easily culturable luminous animals are rare, making many types of experiments intractable. Here we report progress toward keeping the luminous ostracod *Vargula tsujii* through full life-cycles in laboratory aquariums. The California Sea Firefly (*Vargula tsujii*) is found within the clade of ostracods that uses bioluminescence for courtship, but represents a loss of this ability, using bioluminescence purely for defense. *Vargula tsujii* is geographically isolated from closely related species in the Caribbean, found in Southern California and more accessible to our lab. However, almost nothing is known about the life cycle and development of this species. To address this need, we measured hundreds of wild-collected animals. We present multi-dimensional k-means clustering analyses to quantify the size and shape of instar stages for *V. tsujii* development. Within custom aquariums, we show through measurement of lab-reared animals that we raised a full life cycle of *V. tsujii* in the laboratory, a first for any luminous ostracod. These results, combined with descriptions of development and molting times, provide insight into the life cycle of *V. tsujii*. This research will facilitate the understanding of bioluminescence and will allow a host of new laboratory experiments to study sexual dimorphism, sexual selection, and link genes to the diversification of species and courtship signals.

123-4 MITCHELL, TS*; SHEPHARD, AM; SNELL-ROOD, EC; University of Minnesota; *tsmitchell09@gmail.com*

Delicious Ditches: Do Butterflies Prefer Sodium-Enriched Host-Plants Typical of Salted Roadsides?

Sodium occurs in much lower concentrations in plants than in animals and is often limiting in herbivore diets. As a consequence, herbivores are attracted to sodium in many terrestrial ecosystems. Human activity, however, has drastically increased the availability of sodium in certain habitats where it was once rare. For example, we distribute tons of salts on roads during winter for de-icing, and these activities elevate the concentration of sodium in roadside soils and plants. This scenario is particularly interesting in the context of monarch butterfly (*Danaus plexxipus*) conservation, where roadsides are being restored as pollinator habitat, but the ecological consequences of such restoration is unclear. Prior research has shown that small increases of sodium in caterpillar diets can have positive effects on adult performance, but large increases are toxic. Butterflies may indeed be attracted to high sodium roadsides given that many species display "puddling" behaviors as adults, where they seek sodium and other minerals from carrion, dung or mud. Here we present data from an observational field study showing sodium levels in roadside milkweed plants are elevated in plants closer to the roadside, and along higher traffic roads. We also present data from a series of field-and lab-based sodium preference trials using both larvae and adults. Monarchs did not show significant preferences for sodium-enriched plants at levels that are physiologically beneficial. They also failed to avoid sodium-treated plants with toxic sodium levels typical of high traffic roads. Though monarchs frequently use salty roadside habitats and this influences their phenotypes, they are unlikely seeking out roadside habitats because of this elevated sodium. However, our observations of both adult and larval behavior suggest they may indeed consume toxic levels of sodium in some sodium-enriched areas.

P3-11 MITCHELL, CT*; DROTLEF, D; DAYAN, CB; SITTI, M; STARK, AY; Villanova University, Max Planck Institute for Intelligent Systems; *cmitch23@villanova.edu*

Elastic modulus affects adhesive strength of gecko-inspired synthetics in variable temperature and humidity

For nearly two decades the gecko adhesive system has inspired the fabrication of synthetic, gecko-inspired adhesive products. Although derived from the study of the natural system, these synthetics can illuminate details about the mechanisms of the biological system by creating a bidirectional pathway of knowledge. For example, geckos take advantage of small, hair-like structures on their toes called setae. The keratin-based setae soften in high humidity and become more adhesive. Consequently, shear adhesion of live geckos shows that whole animal adhesive performance is significantly impacted by humidity, but this is temperature-dependent. Specifically, whole animal adhesion increases as humidity increases, but only at low temperatures. Interestingly, the same is true for a gecko-inspired synthetic, except when ambient humidity was raised to 80% and temperature remains low. One hypothesis for this discrepancy is that the synthetic lacks the ability to change modulus at high humidity, and that this change is the key to improved adhesive performance in the natural system. To test this hypothesis, we measured adhesive performance by exposing polydimethylsiloxane (PDMS) gecko-inspired synthetic tape samples, each with its own modified modulus of elasticity, to the same set of conditions as previous studies (both the live gecko and synthetic). The results of our work elicit potential improvements for the synthetic and shed light on the adhesion mechanism of the natural system. The striking similarities between synthetic and natural adhesive systems offer the opportunity to conduct research that improves understanding of both systems concurrently.

P1-80 MIYAMAE, J.A.*; BHULLAR, B-A S.; Yale University; *juri.miyamae@yale.edu*

Starting to Smile: Comparative Ontogeny of Mammalian Facial Muscle

Facial muscles are a distinctively mammalian feature responsible for daily activities such as communication, sensory exploration, and feeding. Examination of the fossil record suggests that at least a subset of facial muscles - those responsible for the mobilization of mystacial vibrissae - may have been present in stem-mammalian ancestors as far back as the Mid-Triassic. From their deep evolutionary origins, facial muscles in modern mammals have subsequently diversified into an incredible array, including extreme modifications such as the elephant's powerful trunk and the subtle expressive landscape of the human face. In this study, we compare the ontogeny of facial muscles in various marsupial and placental mammal species using both confocal images of fluorescent immunostained and reconstructed microCT scans of iodine contrast-stained embryos and neonates. Our exploration of the sequence of facial muscle differentiation shows some of the conserved as well as the more clade-specific variations in the developmental process, providing insight on the evolution and diversification of this muscle system.

37-7 MOEGLEIN, MK*; PARK, B; CACHO, NI; OLSON, ME; EATON, DA; DONOGHUE, MJ; EDWARDS, EJ; Yale University, National Autonomous University of Mexico, National Autonomous University of Mexico, Columbia University; *morgan.moeglein@yale.edu*

Leaf Trait Evolution in Viburnum

Though plant leaves are critically important to plant survival, leaf traits are highly variable in many characters, including blade shape, size, margin, and pubescence. Our study aims to expand our understanding of leaf trait evolution by taking a holistic view of the environmental, functional, and genetic pressures influencing leaf traits. We explore this using replicated evolution for leaf syndromes in Mexican *Viburnum*, where species with large, pubescent, toothy (LPT) or small, glabrous, entire (SGE) leaf syndromes have arisen independently multiple times. We characterized microhabitat for individuals with different leaf syndromes at 17 sites in Mexico. We found that though our species with SGE leaves occupied similar environments, our LPT species occupied divergent environments with respect to moisture. The LPT species also showed divergence in their ability to repel water when we measured leaf surface wettability. We also investigated genotypic and phenotypic leaf trait accessibility in a SGE by LPT hybrid swarm and found that in a well genetically admixed population we observed many leaf phenotypes outside of the parental syndromes. This suggests certain combinations of leaf traits could be genetically available in *Viburnum* but are selected against.

P3-105 MOFFITT, M*; REHMAN, F; AHEARN, G; University of North Florida; *n00666596@ospreys.unf.edu*
Preliminary study: Effects of cell density and media changes in Homarus americanus primary cell culture on 3D matrices
The North Atlantic lobster, *Homarus americanus*, is a cold-water invertebrate that is important fundamentally and economically. Physiological transepithelial transport processes for any nutrient, ion, or heavy metal cannot be studied with ease due to the lobster's complex anatomical arrangements. Previous studies on organ dissociation, i.e. hepatopancreas, antennal gland, and/or gills, into cellular suspensions that could be supported *in vitro* to form functional confluent monolayers provide a technical means to study transepithelial transport. In this preliminary study, 3D culture techniques, and cell density seeding, cellular growth, and morphology of cell colonies were investigated to optimize crustacean cell culture in developing a functional confluent monolayer for transepithelial transport studies. It was found that 3D collagen substrata and regular media changes *in vitro* can support colony growth of cells that were likely undergoing mitosis, forming functional junctions with neighboring cells, and pseudopodal growth. Cell density appears to play an important role in the development of a confluent monolayer. Cells must not be seeded too densely but must be seeded at a specific density to form functional junctions. Adaptation of colony growth appears to be dependent upon specific seeding density and regular media changes along with supportive 3D substrata. The goal of these investigations is to yield a functional analysis of transepithelial transport in cultured monolayers in Ussing Slider cell culture cup inserts placed into an Ussing chamber that separates the monolayer apical and basal membranes so that the nature and regulation of solute movement across the cell layer can be ascertained.

P2-72 MOHAN, U; MANJUNATH, M; SANE, S. P.*; National Centre for Biological Sciences, TIFR; *sane@ncbs.res.in*
Multimodal integration by descending neurons in hawkmoths
Flying insects acquire, process and respond to stimuli of multiple modalities at a time scale of a few wing beats to maintain stable flight. Of the various sensory inputs, antennal mechanosensory input and visual input have been shown to be critical for flight in hawk moths. Acquisition and processing of visual inputs is typically slower than that of mechanosensory inputs. How the stimuli from different modalities across different time scales are combined for stable flight is not well understood. We have addressed this question, in the Oleander hawk moth (*Daphnis nerii*) by recording the electrophysiological activity from single descending neurons in the neck connective, while providing the moth various combinations of visual and antennal mechanosensory inputs. These recordings allowed us to identify multiple classes of descending neurons which respond either to only visual stimuli or only antennal mechanosensory stimuli, or both visual and mechanosensory stimuli. There is a clear bandwidth separation in the neurons' response to the visual and antennal mechanosensory stimuli. Neurons responding to antennal mechanosensory stimuli alone are high-pass and encode at frequencies exceeding wingbeat frequency, whereas neurons responding solely to visual stimuli are low-pass and encode at lower frequency visual stimuli. We classified the descending neurons by algorithmically creating circuit models to explain the responses and grouping neurons with similar circuit models. These diverse classes likely correspond to information used in different flight stabilization scenarios.

P2-99 MOLINA, EM*; MENDONCA, MT; Auburn University ; *emm0044@auburn.edu*
Quantification of oxidative stress and baseline immunity to chronic exposure of low levels of DDT in two species of rodents: Peromyscus maniculatus and Sigmodon hispidus
Chronic exposure to low levels of anthropogenic chemicals in the environment continues to be a major health concern. Due to concerns about the effects on humans and wildlife heavily used persistent organic pollutants (POP's), such as dichlorodiphenyltrichloroethane (DDT), were banned. However, their ubiquitous nature and persistence allows them to remain within the environment at sub-lethal levels for decades. Although levels of POP's have been decreasing, they are still high enough to potentially affect physiological functions such as oxidative stress and immunological response parameters. Two species of small mammals (*Peromyscus maniculatus* and *Sigmodon hispidus*) were collected at the Redstone Arsenal, a designated EPA SuperFund site in a historically impacted vs. reference site (*S. hispidus*: n=12 and *P. maniculatus* n=13 vs 19). Soil samples taken from the DDT abatement site still show levels above the Total Threshold Limit Concentration for DDT (i.e. >1ppm), while other reference areas did not. Preliminary data show significant difference in Body Condition Index (BCI) in both species. Both species had significantly higher BCI in the impacted vs the reference site (*P. m.*: T_{28}=3.6, p= 0.0009; *S. h.* T_{25}=2.5, p=0.02). There was also a significant difference in total WBC counts, with both species (*S. h.*: T_{25}=-2.6; p= 0.01; *P. m.*: T_{28}=-2.6, p= 0.01) exhibiting lower counts in the impacted vs the non-impacted area. It has been suggested that reduction in WBC's is due to redistribution from blood to other organs (i.e. skin, mucosal lining, liver) that may enhance immune function during stress. This study can provide critical information on the potential physiological effects of chronic exposure to sub-lethal levels of POPs.

P2-43 MOLNAR, EJ*; WEBB, JF; University of Rhode Island; *emolnar@my.uri.edu*
Elaborations of the Lateral Line System in Tetras (Family Characidae: Order Characiformes)
The aquarium trade provides an affordable and consistent supply of hundreds of fish species that are underutilized in scientific research. In this exploratory study, we examined the mechanosensory lateral line system in the tetras (Order Characiformes; Family Characidae, ~ 1,000 species). We examined two to four individuals in each of seven species from six genera: *Pristella maxillaris*, *Gymnocorymbus ternetzi*, *Hasemania nana*, *Hyphessobrycon pulchripinnis*, *Hemigrammus bleheri*, *Paracheirodon axelrodi*, and *P. innes*. We also examined *Danio rerio* (n=3) and *Carassius auratus* (n=8) (Order Cypriformes; Family Cyprindae) both of which have well documented lateral line systems. Superficial neuromasts (SNs) and canal neuromasts (CNs) were stained with the fluorescent mitochondrial stain, 4-di-2-ASP, and visualized on a dissecting microscope with a GFP epifluorescence filter. After imaging neuromast distributions, fishes were prepared for SEM analysis. Similar groupings of SNs were found among all species examined, including lines or clusters on the caudal edge of the mandible and in a V-shaped line on the operculum, however the relative size difference between CNs and SNs was not consistent among the genera. For instance *P. innesi*has CNs and SNs of similar size, while in species of other genera, such as *G. ternetzi* and *H. bleheri*, the CNs were substantially larger than the SNs. These results reveal that the number, size, and distribution of SNs among genera of tetras should be evaluated as taxonomic characters, which may contribute to our understanding of their systematic interrelationships.

S6-8 MONTOOTH, KL*; DHAWANJEWAR, A; MEIKLEJOHN, CD; University of Nebraska-Lincoln; *kmontooth2@unl.edu*
Temperature-sensitive reproduction and the physiological and evolutionary potential for Mother's Curse
The hypothesis that the strictly maternal transmission of mitochondrial DNA (mtDNA) affords an opportunity for the accumulation and fixation of mitochondrial variants that harm males but not females (i.e., the Mother's Curse) is tantalizing. Yet, direct evidence that mutations in the mitochondria exhibit such sexually-antagonistic fitness effects is sparse. Male-specific mutational effects may seem unlikely, given that the physiological function of the mitochondria is largely shared between the sexes. Nevertheless, male-specific effects could potentially occur if sex-specific cell types or tissues have energy requirements that are differentially impacted by mutations in energy metabolism. Indeed, patterns of gene duplication and evolution suggest the resolution of potentially sexually-antagonistic effects of the mtDNA via the evolution of male-specific expression of nuclear-encoded mitochondrial gene duplicates. Here we employ a model of mitochondrial-nuclear incompatibility in the fruit fly *Drosophila* to test whether there are sex-specific mechanisms underlying temperature-sensitive sterility in males and females. We compare the effects of this mitochondrial-nuclear incompatibility to generate sterility in males and females exposed to ecologically relevant high temperatures at different stages of development, as well as the cellular etiology of sterility in both sexes. We discuss the potential for Mother's Curse in this system in the context of the recent literature supporting or refuting the evolutionary potential for sexually-antagonistic effects of mitochondrial mutations.

P1-124 MOODY, TV*; FAGAN, A; CHAN, E; MASS, S; ST. JOHN, P; SUNY New Paltz; *moodyt1@hawkmail.newpaltz.edu*
Quantifying the Rentention of BPA in Regenerating Planaria
Bisphenyl A (BPA) is a xeno-estrogen that mimics the effects of estrogen and is commonly used in human industrial and consumer products such as plastics, cleaning, health and beauty products, and pharmaceuticals. Due to its common use ecological exposure is nearly unavoidable. In prior research in our lab, micromolar concentration exposure of planaria (*G.tigrina*) to BPA causes a myriad of deleterious effects including dramatic behavioral changes, delayed reactions to stimuli, and severely affected ability to regenerate. This research is focused on quantifying the concentration of BPA absorbed and retained by planaria after a set time of exposure in media. We have used HPLC (high performance liquid chromatography) with fluorescence detection to quantify the amount of BPA present in control solutions. We have attempted to extract BPA from planarian tissue using a 50:50 mixture of a chloroform:methanol solution. However, we have identified other biological macromolecules that co-elute with BPA. We therefore have developed separation techniques to further separate these co-eluting species. We found that amino acids such as tryptophan, tyrosine, and phenylalanine co-elute with BPA and also absorb and emit at the same wavelengths as BPA. These amino acids, which are three of the monomeric units used in abundance in protein, may be interfering with the BPA signal. I plan to further experiment with different techniques, such as solid phase extraction columns and removal of the planarian mucous coat post-BPA exposure, in order to develop an amino acid / BPA separation protocol.

124-3 MOORE, M.E.*; WIEGMANN, D.D.; BINGMAN, V.P.; Bowling Green State University; *mooreme@bgsu.edu*
Shelter Fidelity and Homing Mechanisms in Phrynus pseudoparvulus (Whip Spiders)
The ability to effectively navigate and home is an essential behavior for animals that wander in search for food or mates and has been widely studied in a variety of different species. Nocturnal whip spiders home after traveling on the forest floor and up various tree trunks, which makes them ideal animals to study navigation mechanisms used in both horizontal and vertical dimensions. Previous research into the sensory capabilities of whip spiders suggests that olfactory cues play a significant role in homing while visual cues are minimally involved. The purpose of this study was two-fold. The first was to examine homing fidelity on a vertical surface under laboratory conditions. The second was to examine the underlying homing strategies these animals use to return to a shelter. Phrynus pseudoparvulus were placed individually in an arena with nine different possible shelters positioned on a vertical plane. Phase I of the experiment allowed an animal to home freely for three days, where only one shelter was open (designated the home shelter). In phase II of the experiment, the other eight shelters were opened, and nightly shelter occupancy was determined. In phase III, the home shelter was swapped with the location of an alternative shelter as an animal explored the arena to create cue conflicts. Preliminary results reveal that whip spiders show homing fidelity in phase I and II of the experiments. Within the cue conflict phase, individuals initially homed, which indicates the potential use of self-deposited chemical cues that emanated from the home shelter. After the first day of phase III, however, individuals were inconsistent in following the home shelter. This work indicates that whip spiders probably use multiple sensory cues to relocate shelters.

50-3 MOORE, J.M.*; OSBORN, K.J.; Florida Museum of Natural History, National Museum of Natural History; *jmoore@ufl.edu*
A Targeted Exon-Capture Phylogenomic Approach to Resolve the Phylogeny of Chaetopteridae (Annelida)
The tube-dwelling family Chaetopteridae are unique among annelids in their remarkably tagmatized body plan. Their three-part bodies have allowed morphological specialization for diverse mucus-net filter feeding strategies that vary considerably across the four genera and ~100 species comprising the family. Recent phylogenetic analyses have recovered Chaetopteridae as one of the earliest diverging lineages, sister to all other Annelida except Magelonidae and Oweniidae. Despite recent progress, current understanding of chaetopterid phylogeny is limited by low taxon and gene sampling, low gene tree congruence, and poor support at key nodes. Phylogenomic approaches offer solutions to these issues. Here, we employ a target capture approach to better resolve the phylogeny of Chaetopteridae. Four published chaetopterid transcriptomes and the *Capitella teleta* genome were used to identify homologous exon regions for capture probe design. RNA probes were synthesized for 790 exon regions and used for target capture of dual-indexed libraries for 46 taxa. Post-capture libraries were pooled and paired-end sequenced using Illumina MiSeq with a 600 cycle kit. Sequence data were assembled and aligned for phylogenetic analysis. In addition to the full dataset, three data subsets (25%, 50% and 75% taxon occupancy) were used for phylogenetics. Concatenated, partitioned Bayesian and Maximum Likelihood (ML) phylogenetic analyses were performed for each dataset, as well as species tree analyses under ML. Of 790 targeted regions, 604 usable loci were recovered. The phylogenies are highly congruent among analyses and generally well-supported. The genera *Chaetopterus* and *Mesochaetopterus* were recovered as well-supported sister groups, while paraphyly was confirmed in *Spiochaetopterus* and *Phyllochaetopterus*. The implications of the phylogeny for taxonomy and body plan evolution are discussed.

3-6 MOORE, ME*; HILL, CA; KINGSOLVER, JG; MOORE, Megan; Univ. of North Carolina, Chapel Hill; *melmoore@live.unc.edu*

Mutually Assured Destruction: Repeated Heat Stress Kills Parasitoid Eggs and Disrupts Host Development

Repeated exposure to high daily temperatures can have large impacts on ectothermic organisms, especially if those temperatures approach the upper thermal limits. The effects of fluctuating, sublethal temperatures have been explored for single organisms, but little is known with regards to multi-species systems. *Cotesia congregata* is a hymenopteran parasitoid that uses the larval stage of the sphinx moth *Manduca sexta* as a host for larval development. Host manipulation early in parasitization is crucial for successful wasp development. Exposure to stressful conditions soon after oviposition holds the potential to disrupt physiological processes vital to *C. congregata* survival. Previous work in this system has shown that parasitized *M. sexta* caterpillars reared continually at 30°C±10°C have no parasitoid emergence, and exhibit abnormal developmental traits. To explore the effects of temperature and repeated heat stress on early parasitoid development, we subjected 3rd instar *M. sexta* parasitized with *C. congregata* to one of two diurnally fluctuating "heat shock" treatments (daily maximum of 40°C or 42°C) for 1-4 days. Under control conditions, wasp emergence occurred in all parasitized *M. sexta* caterpillars. Our results from the "heat shock" treatments show that both maximum temperature and the number of exposures decrease the proportion of hosts with parasitoid emergence. Hosts without wasp emergence displayed abnormal physiology and development, and inevitably perished as larvae. Our results indicate that both the temperature and repetition of heat stress have important consequences for host-parasitoid interactions.

73-3 MOORE, T Y*; BRUDER, D K; DAVIS RABOSKY, A R; VASUDEVAN, R; Unversity of Michigan; *taliaym@umich.edu*

Decoupling coupled anti-predator signals with a bio-inspired snake robot

Venomous coral snakes and their harmless mimics exhibit conspicuous coloration and arrhythmic behavior patterns that deter avian predators. Because these traits cannot be independently varied in living animals, it is difficult to determine the relative contribution of each trait to the overall signal. Robots can be designed to independently vary traits that are coupled in nature, making it possible to mimic extant, extinct, and theoretical morphologies to test evolutionary and ecological hypotheses. We have collected quantitative snake behavioral and color pattern data to design soft snake robots that enable the simultaneous study of both coloration and behavior for the first time. Each of these robots is composed of an elastomer tube with cotton fibers wound around it. The fibers enact a volumetric constraint which imposes specific deformations such as extension, torsion, bending, and coiling upon pressurization of the inside of the tube. By wrapping fibers in an appropriate pattern, such deformations can be combined to mimic specific snake-like motions under a varying internal pressure. These robots are pneumatically actuated and made from biocompatible soft materials, making them safe and resilient enough to be used in the field without risk of injuring live predators. By recording the response of snake predators to these robots, we will gain a mechanistic understanding of how multiple traits coevolve to form a complex signal.

43-1 MOORE, MS*; BURE, CM; PATROSE, RP; RASHEED, AR; BOONE, BM; KNIGHT, JK; POTEREWICZ, GM; GROSS, VS; RUSSELL, AL; DáVALOS, LM; Arizona State University, Mesa, Stony Brook University, Stony Brook, Pressure BioSciences, Inc., Medford, Grand Valley State University, Allendale; *marianne.moore@asu.edu*

Analyzing the Proteomes of Bat Wing Biopsies to Uncover Characteristics of Resistance to White-Nose Syndrome

Bat immune systems may first recognize *Pseudogymnoascus destructans* (*Pd*), the causative agent of white-nose syndrome (WNS), in the skin where the pathogen invades, and characteristics of immune defense may help explain differential disease and mortality across species. Yet, baseline expression levels of immune system components (e.g. those that survey for pathogenic intruders) and mechanisms of skin immune response upon exposure to *Pd* are not well described among species. We optimized high throughput mass spectrometry (MS) based proteomics analysis using pools of three 2mm wing biopsies (average mass = 140 µg ± 62 µg) collected from each of 155 bats across five species variably impacted by WNS. Our sample collection was designed to include two endangered species showing resistance to WNS and to sample susceptible species within and outside the affected area. Average total protein yield across all samples was 2.6% ± 2.6%. Nearly half of our samples (~47%) provided the ideal mass (>2 µg) needed for mass spectrometry. We are comparing MS results to generate skin protein profiles of resistant and susceptible species and are specifically targeting small antimicrobial peptides (AMPs), which may underlie resistance and lead to an effective control. At least two species included in our study, *Eptesicus fuscus* and *Myotis lucifugus*, can be distinguished by their skin proteomes, which include differences in AMPs. Our results are being used to uncover mechanisms by which some species are protected from invasion by *Pd* and to predict how susceptible species may recover from *Pd* exposure.

116-6 MOORE CRISP, AL*; LEE, DV; Stockton University, University of Nevada, Las Vegas; *leximoore@gmail.com*

Who digs, who hops, who tells your story?

To quantify oscillatory digging forces, Forces measured by the tunnel-tube were analyzed using Fourier analysis as a function of frequency. The tunnel-tube was used here to quantify scratch-digging forces in three closely-related rodents: pocket gophers, kangaroo rats, and pocket mice. Animals from each species dug in soil from their trapping site packed into the tunnel-tube. Digging frequency was lowest in pocket gophers at 15 Hz and highest in kangaroo rats at 22 Hz. This was unexpected as pocket mice have a lower body mass, but dug at a frequency of 19 Hz, a slower speed than kangaroo rats 1.5x their size. Scaling of digging frequency to body mass results in a scaling exponent of -0.15, hinting at elastic similarity. Results of the Fourier analysis of force showed that vertical force scaled with body mass, and fore-aft force (into the digging substrate) scaled with positive allometry. It remains unclear whether this trend reflects true positive allometry or digging specialization in pocket gophers vs the two smaller species.

9-5 MORAN, C/J*; JEBB, K; YOUNG , C; GERRY, S/P; The Citadel, Fairfield University; *cmoran3@citadel.edu*
The Effects of Torpor Inducing Temperatures on Temperature Fish Muscle
As non-migratory fishes, labrids from the Northwest Atlantic must be able to endure changes in temperature from 25 ° C to 0 ° C. During the winter both tautog (*Tautoga onitis*) and cunner (*Tautogolabrus adspersus*) enter into a state of extended torpor where metabolic activity is low. Cunner do this in inshore reefs while tautog make short migrations to deep reef/wrecks overwintering habitats. These habitats experience different temperatures throughout the winter with the inshore (cunner) habitat experiencing colder temperatures than the deep-water habitats. Additionally, the northern geographical range of cunner is far greater than the tautog. Given the differences in their overwintering behaviors and ranges, we predicted that muscle acclimation will differ between these species. We tested the hypothesis that cunner muscle will be better acclimated for operating in colder temperatures using workloop experiments on the primary locomotor muscle (abductor superficialis). We found that cunner muscle acclimated for cold temperatures was faster to contract and relax than tautog muscle acclimated at the same temperature. Additionally, cunner produced more force and more power at colder temperatures. Tautog muscle was more affected by temperature than cunner muscle, while showing less plasticity to acute temperature changes. Given their more southern range and more thermally stable overwintering habitats we conclude that tautog muscle cannot acclimate to temperature as well as cunner. Given the projected poleward shift of temperate animals we expect that cunner and tautog will begin competing for habitat and prey resources in northern latitude where this type of competition never occurred previously.

19-4 MOREHOUSE, NI*; ECHEVERRI, SA; BRUCE, M; LONG, S; JAKOB , E; ZUREK, DB; U Cincinnati, UPittsburgh, UMass Amherst, UMass Amherst; *nathan.morehouse@uc.edu*
Managing Distraction: How Male Courtship Displays Attract and Retain Female Visual Attention in a Jumping Spider
Courtship displays are among nature's most exuberant expressions of biodiversity. But why are they often so complex? One underexplored possibility is that complex male displays function to manage female distractedness. Female attention is limited, and must often be split between mate assessment and other competing tasks, such as foraging and predator avoidance. Thus male displays may evolve to effectively capture and retain female attention. We investigated this hypothesis in the jumping spider *Habronattus pyrrithrix*, where male courtship displays involve complex movement sequences, bright colors, and vibrational songs. We used live interaction, video playback, and eyetracking studies to better understand how male courtship traits capture, retain, and manipulate female visual attention. First, we find high levels of female distractedness: in live interactions, females only spent ~27% of their time facing displaying males, whereas males faced prospective mates >99% of the time. However, male display elements such as first leg waves and third leg knee movements increase female attentiveness. In playback studies, male courtship waves are more effective than locomotory movements at capturing female attention, and waving movements made males more salient, particularly against complex and/or moving backgrounds. In live interactions, males dynamically modulate their waves: males increase their wave amplitude with increasing distance from females, and when background complexity increases, males move closer to females to increase the salience of their waves. Finally, eyetracker studies indicate that male colors and movements influence where females direct the gaze of their moveable principal eyes. We discuss how female attention may have shaped male display complexity in this and other species.

57-8 MORRIS, ZS*; PIERCE, SE; ABZHANOV, A; Museum of Comparative Zoology and Department of Organismic and Evolutionary Biology, Harvard University, Department of Life Sciences, Imperial College London; *zmorris@fas.harvard.edu*
The role of craniofacial growth zones in shaping crocodylian snouts
Crocodylian snout shape, the region of the skull in front of the eyes, is tightly linked with dietary ecology. Some species, like *Tomistoma schlegelii*, have incredibly elongated snouts while others, like *Osteolaemus tetraspis*, have short, wide snouts. Although species form a continuum between these extremes, little is known about the developmental processes that determine differences in snout length. Prior study of *Alligator mississippiensis* revealed early facial proliferation is distributed throughout the snout and, unlike birds, is not constrained to an apical growth zone. Later stages with well defined cranial cartilages lack obvious growth plates, similar to post-hatching Anole lizards. To study how snout shape differences arise, we injected EdU *in ovo* to quantify proliferation at key developmental stages in three species with different snout lengths (*A. mississippiensis*, *O. tetraspis*, and *T. schlegelii*). This marker, in concert with histological staining, allowed us to test whether differences in the rate of cellular proliferation are apparent from the start of facial elongation or if differences in length are related to how long proliferation is maintained during snout morphogenesis. Although differences in facial shape are distinct as early as Ferguson stage 17, patterns of proliferation at earlier stages are not. Our data suggest a model wherein proliferation rate decreases earlier in blunt species than slender species. Genes which modulate proliferation are, therefore, ideal targets for future studies of developmental mechanisms for the evolution of crocodylian cranial diversity.

19-1 MORRIS, DJ*; OUTOMURO, D; MOREHOUSE, NI; University of Cincinnati; *morri2dd@mail.uc.edu*
Understanding the Evolution of Color Vision Via Adaptive Walks Through Discrimination Landscapes
Color vision allows for increased discrimination of environmental stimuli, aiding organisms in identification of suitable resources amid complex backgrounds, navigation, and inter- and intraspecific visual communication. Different groups of organisms have evolved visual systems with different numbers of photoreceptor types, and with different peak sensitivities. While numerous studies have focused on the importance of photoreceptor sensitivities relative to ecological function, few have investigated why the number of photoreceptors varies between organismal groups. We quantitatively compared the discriminability of additional photoreceptor types to the discriminability available from simply adjusting photoreceptor peak sensitivities. We used receptor-noise-limited models to generate discrimination landscapes for visual systems with different numbers of photoreceptor types, using spectral datasets from different ecosystems. We employed an adaptive walk procedure mimicking characteristics of photoreceptor sensitivity evolution, and we tracked the moves through these discriminability landscapes while modifying additional visual system parameters. We then analyzed whether gains in discriminability from the addition of photoreceptor types were greater than those achieved solely from photoreceptor tuning. Additionally, we compared discriminability landscapes between ecosystem-specific datasets to consider how landscape features may affect the evolutionary specifics of photoreceptor tuning.

S4-3 MORTIMER, B; Univ. of Oxford, UK;
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Vibration Landscapes: the Role of Materials in Vibrational Information Transfer

For millions of years, organisms have been sensing vibrations generated by the moving world around them. The vibrations that propagate through and along solid materials are often overlooked, but are an important information source for a wide variety of organisms, from worms and spiders to elephants and humans. The materials over which vibrational information is transmitted collectively form ‘vibration landscapes'. They are often heterogeneous, and impose physical constraints on information transfer, including energy loss, distortion and filtering. Animals can mitigate these physical constraints through adaptations in vibration generation and sensing to suit particular material types. Some may choose which materials to use for information transfer. One strategy that is employed by web-building spiders is to make their own vibration landscape for information transfer. Orb-weaving spiders can adjust the properties of their silk materials and web structures to modify vibrational information transfer. To achieve this, spiders have evolved a uniquely tunable material, dragline silk, which is used as a multifunctional material fibre for mechanical and sensing functions.

139-3 MOSS, A.G.*; MADIN, L.P.; Auburn University, Woods Hole Oceanographic Institution; *tony@auburn.edu*

The ciliated groove of salps: A new perspective

We examined the ciliated grooves of *Pegea socia*, *Salpa maxima* and *Cyclosalpa affinis* by video and scanning electron microscopy of the anterior ciliated pouch, to reveal details of the ciliary organization and activity. *P. socia* and *S. maxima* display very similar overall organization, with lateral fields of cilia that beat with symplectic metachrony (i.e. waves in direction of the power stroke) that concentrate algal particles and transport them to the midline of the ciliated groove inside the pouch. The algae, heavily wrapped in mucus concentrate, are excluded from the anterior pouch by ciliary action and do not pass through a ciliary pump formed of knifelike, flattened cirri. In contrast, single mucous-free styrene fluorescent particles pass through the ciliary pump directly into the bloodstream. The upper limit for particle passage is ~15 µm dia; they are forced at high speed into the blood, indicating that the particles are under significant pressure. Particle size correlates with circulation access pore diameter in the radialmost regions of the pouch. *C. affinis* lacks the pouch-enclosed ciliated complex and instead bears a serpentine ciliary band that covers the posterior wall of the anterior chamber, in roughly the same location as the ciliated groove pouch in *P. socia* and *S. maxima*. Transport of fluids and associated algal particles is unclear in this species. There appears to be no access to the blood volume from the *C. affinis* ciliated band. Its primary function appears to be the clearance of material from the anterior chamber so that it flows into the orthogonally woven algae-collecting mucus net, which arises from ciliated bands in the inhalent chamber.

101-6 MOSSMAN, JA*; RAND, DM; Brown University;
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Mitochondria, sex and nuclear gene expression: Cursing the Mother's Curse

Mitochondria perform many key roles in their eukaryotic hosts, from integrating signaling pathways through to modulating whole organism phenotypes. The >1 billion years of nuclear and mitochondrial gene co-evolution has necessitated coordinated expression of proteins in the two-genome-encoded electron transport chain. How mitochondrial DNA (mtDNA) variation modifies host fitness has proved a challenging question but has profound implications for evolutionary and medical genetics. In *Drosophila*, we have previously shown that when mtDNA haplotype substitutions are performed in isogenic nuclear backgrounds, the amount of genetic distance between mtDNA molecules is a poor predictor of whole organism phenotypes. Crucially, underlying most phenotypic variation is protein abundance, which is ultimately regulated by gene expression. Here, we tested the effects of mtDNA haplotype variation on gene expression in *Drosophila* under standardized conditions. Using the Drosophila Genetic Reference Panel (DGRP), we constructed a panel of mitonuclear genotypes that consists of factorial variation in nuclear and mtDNA genomes, with mtDNAs originating in *D. melanogaster* (2x haplotypes) and *D. simulans* (2x haplotypes). We show that mtDNA haplotype variation unequivocally alters gene expression in both females and males, and mitonuclear interactions are pervasive modifying factors for gene expression. In females, there was enrichment for egg shell-related gene ontology terms with mtDNA haplotype variation, while males were enriched for chitinase activity-related genes. However, there was appreciable overlap between the sexes in those genes that were modified by mtDNA variation. We are now exploring these gene hubs in a systems biology context with the ultimate goal of characterizing predictable regulatory elements that are associated with mtDNA haplotype variation and gene expression.

78-1 MOTTOLA, G*; VASEMÄGI, A; NIKINMAA, M; ANTTILA, K; University of Turku, Swedish University of Agricultural Science; *giomot@utu.fi*

Phenotypic plasticity of thermal tolerance in three-spined sticklebacks (Gasterosteus aculeatus) from natural and thermally polluted areas

Climate change will increase both the average temperature of environment but also the frequency and duration of extreme thermal events as has been seen during summer 2018 in the whole northern hemisphere. These heat waves have led to mass fish death events around the world. The ability of ectotherms to respond to these sudden temperature changes can be exerted throughout a mechanism of phenotypic plasticity. There are, however, no studies how fish that have experienced long term (decades) increase of temperature in their habitat are able to respond to heat waves. The capacity of individuals to change their tolerance will, nevertheless, define survival capability of entire populations. We evaluate the thermal plasticity of critical thermal maximum (CTmax) in six populations of three-spined sticklebacks to a heat wave (increase of environmental temperature by 11°C for 8 days). Populations were from coastline and from areas that have been warmed by ~10°C by nuclear power plants for four decades in Finland. Surprisingly, the decades of warming has not increased the thermal tolerance of sticklebacks. Yet, all the individuals from each population were able to increase their tolerance after the heat shock by 2.5-4°C ($p < 0{,}001$), but again there were no significant differences between the populations. We propose that adaptive capacity to increase the upper thermal tolerance may be limited in three-spined sticklebacks. Yet, studied sticklebacks possess some phenotypic plasticity to respond to heat waves as long as waves stay below their upper thermal limits.

P3-148 MOUNGER, JM*; HUGHES, AR; GEHRING, CA; ROBERTSON, MH; VOORS, S; RICHARDS, CL; University of South Florida, Tampa, FL, Northeastern University, Boston, MA, Northern Arizona University, Flagstaff, AZ; *jmounger@mail.usf.edu*

Effects of genetic diversity and epigenetic change on trait variation in the foundation plant Spartina alterniflora

While ecological genetics approaches have informed us about the structure of genetic diversity in natural populations, we still know surprisingly little about the mechanisms that permit organisms to adapt to variable environmental conditions. Using MS-AFLP, our previous work showed a weak, but significant correlation of epigenetic variation with habitat in the salt marsh foundation plant Spartina alterniflora. In this study, we used the more powerful genomics approach of epigenotyping-by-sequencing (epiGBS) to examine differential methylation polymorphisms (DMPs) and single-nucleotide polymorphisms (SNPs) to investigate genetic and epigenetic diversity in natural populations across salinity gradients, and from a reciprocal transplant study of S. alterniflora. In addition, we used sequencing of the ribosomal ITS region to identify variation in fungal endophyte communities, which may be particularly beneficial under stressful environmental conditions. We will present DMPs and SNPs, and associated candidate genes that are correlated with trait response, environmental gradients and symbiotic relationships in this critical coastal species.

P3-27 MOVSESYAN, T*; STOVER, KK; OLBERDING, JP; AZIZI, E; Univ. of California, Irvine; *tmovsesy@uci.edu*

Digging into the burrowing kinematics of Hurter's spadefoot toad

Burrowing is crucial for many terrestrial anurans as it provides protection from predators, high temperatures, or desiccation, as well as access to otherwise inaccessible food resources. In particular, the spade foot toad (*Scaphiopus hurterii*) is well known for its burrowing capabilities. These toads use relatively short hind limbs with a spade-like keratinous tubercle on the foot to excavate burrows. However, the kinematics of this movement remains unclear and the significance of this specialized morphology is unknown. Given the importance of ankle extension in other anuran locomotor behaviors, we hypothesized that this motion would also be critical for burrowing. We examined burrowing behavior in 5 toads using 3D high-speed video. The toads used one limb to dig, the working side, and the other for support, the bracing side. The motion of the working limb was cyclical with two phases, pushing and re-positioning, with an average cycle duration of 256 ± 74 ms. The motion of the joints was tracked by digitizing anatomical landmarks on the toads' limbs. The pushing phase included flexion of the hip (average of -9.0 ± 1.1°) and dorsiflexion of the ankle (average of -29.6 ± 4.3°), indicating that ankle muscles are not contributing significant mechanical work. On the other hand, the knee extended up to 15.8 ± 4.9° during pushing, suggesting that this motion provides much of the work for digging. This finding is reflected in the lower proportion of hind limb muscle mass associated with ankle extensors (11%) compared to other non-burrowing species (19%). Future experiments will identify the morphological or physiological specializations of the knee extensors that may relate to their crucial role in this behavior.

21-2 MOYEN, NE*; SOMERO, GN; DENNY, MW; Stanford University; *nmoyen@stanford.edu*

Heating Rate Affects Thermal Tolerance in Intertidal Mussels

During tidal cycles, intertidal animals may undergo large body temperature changes as exposure between water and air alternates. The California mussel Mytilus californianus (the dominant competitor for space on many shores) is a unique model for exploring how animals cope physiologically with extreme thermal stresses, as they cannot behaviorally respond (e.g. seek shade). As such, mussels can provide important predictive information about how climate change will affect other intertidal animals. Cardiac thermal tolerance, measured as the Arrhenius break temperature (ABT, temperature when heart rate abruptly declines) or flat-line temperature (FLT, temperature when the heart stops), is an excellent index for quantifying a mussel's ability to cope with heat stress. Thermal tolerance tests entail heating mussels in air or water at constant rates until ABT and FLT occur. However, it is unknown whether heating rate (which varies widely in the field) independently affects ABT or FLT, and if mussels acclimatized to different intertidal heights respond differently. M. californianus from low- and high-zones (0.56 vertical m apart) were tested in air at various heating rates from 2.4 to 8.6 °C/h (spanning field measured rates), while measuring heart rate via infrared sensor. High- and low-zone mussels had similar ABT up until heating rates of ~5 °C/h, thereafter high-zone mussels' ABT increased with heating rate while low-zone mussels' ABT remained unchanged. FLT was unaffected by zone or heating rate. Overall, heating rate affects cardiac thermal tolerance in high- but not low-zone mussels. Therefore, heating rate needs to be accounted for during lab-based tests comparing mussels from differing intertidal zones, and more importantly when predicting the ecological consequences of our warming climate.

64-2 MUIJRES, FT*; KARáSEK, M; DE WAGTER, C; REMES, BDW; DE CROON, GCHE; Experimental Zoology Group, Wageningen University, The Netherlands., Micro Air Vehicle Laboratory, Delft University of Technology, The Netherlands.; *florian.muijres@wur.nl*

A Bio-inspired Free-flying Robot Reveals that Flies Use Torque Coupling in Rapid Banked Turns

The evasive banked turn of a fly is among the most rapid flight maneuvers in nature, which it executes using small adjustments in its wingbeat pattern. It is suggested that, after open-loop turn initiation, flies control the bank dynamics using a PI controller based on sensory input from halteres; the yaw rotations are suggested not to be controlled throughout the maneuver, resulting in large sideslip at the turn's end. We tested these notions, by replaying banked turns of fruit flies on a newly-developed bio-inspired flying robot. Like insects, the robot steers by adjusting the motion of its flapping wings, and autonomous flight is achieved using on-board auto-pilot and sensors, including a haltere-like gyroscope. The robot's banked turns, controlled using a gyro-based PI-like controller, resembled those of fruit flies remarkably well, suggesting that fruit flies use a comparable controller based on haltere input. Yaw dynamics was also similar between the fruit flies and robot, whereby both rotated into the turn. This yaw movement reduced sideslip and might thus increase escape performance. Because the robot's yaw control was turned off, the yaw movement must have been produced passively. Using an aerodynamic model of flapping flight, we showed that a translation-induced coupled yaw torque caused this yaw movement. Because many flying animals tend to produce banked turns using flapping wings, the use of this mechanism might be more common in nature.

S1-7 MUIR, Christopher D; Univ. of Hawaii, Manoa; *cdmuir@hawaii.edu*
Synthesizing evolution and physiology using leaves, trees, and math
Organismal biology often advances through two iterative stages: 1) analyzing models that integrate fundamental physical and chemical laws with biology to predict which phenotypes natural selection favors under what ecological conditions; and 2) testing model predictions by comparing observed patterns of trait evolution with that predicted by competing models. I use stomata, the microscopic valves on the leaf surface that regulate carbon uptake and water loss, as a model system for addressing basic questions about organismal physiology and evolution. In most plants, stomata are located only on the lower leaf surface, but many plants have stomata on both surfaces. The distribution of these phenotypes is highly nonrandom across flowering plants, indicating evolutionary constraint, but not necessarily adaptation. To predict the distribution of phenotypes under an adaptive hypothesis, I analyze an evolutionary physiological model based on leaf biophysics to ask how stomatal traits should evolve along light gradients. Compared to an alternative model of developmental constraint, the evolutionary physiological model explains several independent patterns of stomatal evolution in flowering plants. The combination of integrative models and comparative biology indicate that stomatal evolution is an important part of adaptation to different light environments. More broadly, investigating stomatal evolution provides new insight into major questions about the evolution of organismal form that are especially to challenging to study.

P2-172 MUKHALIAN, J*; MCBRAYER, L; Georgia Southern University; *jm18915@georgiasouthern.edu*
Variation in metabolic rate and immune response of lizards from long-leaf pine and scrub habitats
Habitat management, by definition, alters an environment to achieve specific outcomes for conservation, preservation, or use of natural resources. Common management techniques include prescribed fire, timber harvest, or species removal; thus, each management protocol has a variety of negative or positive effects on constituent species. In some cases, habitat management techniques may benefit some species, while having negative consequences on non-target species. Long leaf pine and Florida scrub habitats in the Ocala National Forest (ONF) in central Florida undergo prescribed burning (long leaf) and clearcutting (scrub), thereby leading to substantially different microhabitats for small ectotherms such as lizards. As such, these habitats lead to certain physiological adaptations. The Florida Scrub Lizard (*Sceloporus woodi*) is endemic to peninsular Florida and resides in the managed long leaf and scrub habitats in the ONF. Lizards from each habitat are known to differ in key traits such as activity time, thermal environment, and predation rate. Therefore, in this study, we will examine variation in metabolic rate and immune response (swelling), in lizards from each habitat type to test if physiological adaptations are occurring among subpopulations.

97-3 MUNLEY, KM*; DEYOE, JE; REN, CC; DEMAS, GE; Indiana University; *kmunley@indiana.edu*
Melatonin mediates seasonal transitions in circulating androgen profiles and aggression in male Siberian hamsters
Some seasonally-breeding animals exhibit equivalent or increased levels of aggressive behavior during the short-day (SD) photoperiods of the non-breeding season, despite gonadal regression and reduced circulating androgen levels. While the mechanisms underlying SD increases in territorial aggression are not well understood, previous work from our lab suggests that pineal melatonin (MEL) and the adrenal androgen dehydroepiandrosterone (DHEA) are important in facilitating non-breeding aggression in Siberian hamsters (*Phodopus sungorus*). To characterize the role of melatonin (MEL) in modulating seasonal transitions in aggressive behavior, we housed male hamsters in long days (LD) or SD, treated them with either timed MEL or saline injections, and quantified aggression after 3, 6, and 9 weeks of photoperiodic housing. Furthermore, to assess whether MEL mediates seasonal shifts in gonadal and adrenal androgen synthesis, serum testosterone (T) and DHEA concentrations were quantified 36 h before and immediately following an aggressive encounter. LD hamsters administered MEL (LD-M) exhibited intermediate levels of aggression and basal T levels relative to LD and SD animals, and aggressive encounters reduced serum DHEA levels, yet increased serum T levels. Interestingly, LD and SD hamsters exhibited distinct relationships between circulating androgen profiles and aggressive behavior, in which changes in serum T following an aggressive encounter (ΔT) were negatively correlated with aggression in LD and LD-M animals, while ΔDHEA was positively associated with aggression in SD animals. Collectively, these findings suggest that SD hamsters transition from synthesis to metabolism of circulating androgens following an aggressive encounter, a mechanism that is likely modulated by MEL.

121-7 MUNOZ, MM*; SALAZAR, JC; LONDONO, GA; CASTANEDA, MR; Virginia Tech, ICESI; *mmunoz5@vt.edu*
A test of the island effect in the physiological evolution of anoles.
Phenotypic evolution is often rapid on islands, resulting in numerous, ecologically diverse species. Although adaptive radiation proceeds along various phenotypic axes, the island effect of faster evolution has been mostly tested with regards to morphology. Here, we leverage the physiological diversity and species richness of *Anolis* lizards to examine the evolutionary dynamics of three key traits: heat tolerance, body temperature, and cold tolerance. Far from an island effect, we discovered faster heat tolerance evolution in mainland lineages. Island and mainland anoles evolve toward distinct trait optima, with island taxa being more warm-adapted. Higher optima and slower evolution are consistent with the Bogert Effect, or evolutionary inertia due to behavioral buffering. Correspondingly, island lizards thermoregulate more than mainland species, despite occurring in similar thermal environments. Lower physiological limits, in contrast, cannot be behaviorally buffered against selection and, not surprisingly, cold tolerance evolution did not differ between habitats. Given ecological release from competitors and predators, the costs of thermoregulation may be lower on islands. As a corollary, ecological opportunity on islands may actually slow, rather than accelerate, evolution. Our results emphasize that physiological diversification is a key feature of adaptive radiation, and that behavior can illuminate the numerous interactions shaping its evolution.

S7-1 MUNOZ, MM*; PATEK, SN; MUNOZ, Martha; Virginia Tech, Duke; *mmunoz5@vt.edu*

Biomechanics as a Pacemaker for Evolutionary Diversity

All biological motion is dependent on the fundamental laws of physics. Mechanical rules shape how organisms can move, feed, and reproduce, thus impacting all aspects of evolutionary fitness. Here we discuss how the field of evolutionary biomechanics has developed into a deeply quantitative and integrative science, resulting in a much richer understanding of how physics impacts the dynamic process of evolution. Novel technologies are revolutionizing evolutionary biomechanics. New imaging methods and computing infrastructure allow the generation, storage and analysis of vast quantities of photographs, 3D scans and videos. Analytical approaches are accelerating by the development of machine learning techniques and crowd-sourcing platforms. Concomitantly, evolutionary analysis of the data, which requires the building of large time-calibrated phylogenies, is being facilitated by Next Generation Sequencing and rapid advances in comparative phylogenetic methods. Now, more than ever, we are couching major biomechanical patterns - power amplification, many-to-one mapping, mechanical sensitivity, to name a few - in a macroevolutionary framework. Combined, these developments are rapidly elucidating the governing principles that causally, and predictably, link physics to phenotypic diversity.

P1-25 MUNTEANU, VD*; DIAMOND, KM; SCHNEIDER, NG; RILEY, AB; MCKAMY, AJ; BLOB, RW; Clemson University; *vmuntea@g.clemson.edu*

Effects of Ecological Transitions on Locomotor Morphology: Do Changes in Bone Loads Have Implications for Limb Elongation in Arboreal Tetrapods?

Across vertebrate diversity, limb bone morphology is typically expected to reflect differences in the habitats and functional tasks with which species contend. Arboreal vertebrates are often recognized to have longer limbs than terrestrial relatives, a feature thought to help extend the reach of limbs across gaps between branches. Among terrestrial vertebrates, longer limbs can experience greater bending moments that might expose bones to a greater risk of failure. However, changes in habitat or behavior can impose changes in the forces that bones experience. If locomotion imposed lower loads in trees than on the ground, such a release from loading demands might have produced conditions under which potential constraints on the evolution of long limbs were removed, making it easier for them to evolve in arboreal species. We tested for such environmental differences in limb bone loading using the green iguana (*Iguana iguana*), a species that readily walks over ground and climbs trees. We implanted strain gauges on the femur and compared loads between a level-stiff surface, a level-compliant surface, and an inclined (60 deg) surface, with the latter two treatments modeling substrate conditions of tree branches and trunks, respectively. Shear strains were similar across treatments; however, counter to expectations, bending strains were greater for both compliant and inclined surfaces than for stiff, level ground. These results suggest that evolutionary changes in limb length among arboreal species may have occurred despite increases in limb bone loads during movement through the trees. The advantages of longer limbs for arboreal taxa may, therefore, have outweighed potential costs.

P3-152 MURPHY, KM*; BODENSTEINER, BL; DELANEY, DM ; STRICKLAND, JT; JANZEN, FJ; Auburn University, Virginia Polytechnic Institute and State University, Iowa State University, U. S. Fish and Wildlife Service, Iowa State University; *kmm0155@tigermail.auburn.edu*

Nest Temperatures Alter Survival and Emergence of Painted Turtle (Chrysemys picta) Offspring

Environmental conditions during early development critically affect morphology, behavior, and survival. However, nest temperature in oviparous species also could affect post-hatching traits of offspring, such as emergence behaviors. We monitored Painted Turtle (*Chrysemys picta* (Schneider, 1783)) nests to examine how thermal conditions influence offspring survival and nest emergence. We recorded hourly temperatures within nest cavities during embryonic development in summer 2016 and after hatching through the following January. Hatching success was improved by thermal moderation within nests during summer, whereas post-hatching survival was enhanced by warmer average fall temperatures and greater thermal maxima in winter. Emergence of neonates from nests was observed from 19 March through 12 May 2017. More hours spent below 0° C in nests increasingly delayed onset of emergence. For nearly all nests with live offspring, siblings did not emerge en masse, but instead departed the nest across multiple days. This emergence duration was positively correlated with the thermal maxima nests experienced in summer, fall, and winter. Differences in thermal environments among nests during embryonic development and after hatching elicit considerable variation in survival and emergence timing of *C. picta* hatchlings.

111-7 MURPHY, DW*; OLSEN, D; KANAGAWA, M; KING, R; KAWAGUCHI, S; OSBORN, J; WEBSTER, DR; YEN, J; Univ. of South Florida, Georgia Institute of Technology, Australian Antarctic Division, Univ. of Tasmania, Georgia Institute of Technology; *davidmurphy@usf.edu*

Antarctic Krill Schools: Linking Three Dimensional Structure and Function

Animals may take up certain positions within collectively swimming or flying groups in order to reduce their cost of locomotion or to enhance their ability to sense prey, predators, or conspecifics. Antarctic krill (*Euphausia superba*) form massive schools which may extend for several kilometers horizontally and for hundreds of meters vertically. The three-dimensional structure of such schools may reveal their adaptive advantage. We used stereophotogrammetric videos of Antarctic krill schooling in the laboratory to determine the internal structure of such schools. For krill with a mean body length of 34 mm (measured from telson tip to the front of the eyeball), the mean school density was 4244 animals m^{-3} at a mean swimming speed of 68 mm s^{-1} and mean nearest neighbor distance of 47.1 mm. With a polarity of 34°, the krill reached a similarly high level of organization as fish schools. The nearest neighbor position distribution is anisotropic and shows a preference for Antarctic krill to swim in the propulsion jet of their nearest neighbor, likely to sense its hydrodynamic signal. The distribution also shows that Antarctic krill avoid having a nearest neighbor overhead, possibly to avoid obstruction of the light it needs for orientation. Structure in the nearest neighbor position distribution is also likely created by the tight packing of elongated krill bodies within the school. Further, the distributions shed light on how various hydrodynamic mechanisms might lead to energy savings for krill swimming in schools.

45-3 MURPHY, C.*; DAILY, D.; MARX, M.; LAPSERITIS, J.; NEIMEYER, M.; JOHNSTON, E.; GUARENDI, A.; MOORE, M.; Naval Undersea Warfare Center, Anderson Cabot Center for Ocean Life at New England Aquarium, International Fund for Animal Welfare, Woods Hole Oceanographic Institution, Biology Department; *christin.murphy@navy.mil*

A Photogrammetric Method for Modeling Body Form in Stranded Large Whales

Large whale strandings offer fleeting opportunities to collect morphology data on largely inaccessible species. Necropsies performed in beach settings are subject to environmental variables that necessitate immediate research team mobilization and rapid data collection. 3D data collection methods could dramatically increase the amount of information obtained during necropsy procedures and allow for a complete model of the body form (including injuries) to be assembled. We explored a photogrammetric method that utilizes a 360º series of photos around the animal to stitch together a 3D model of the body. Photo collection requires only a single smartphone camera and low-cost anchoring targets to be available on the beach. This allows the photo collection portion of the process to be accessible to all stranding response teams. Advanced processing tools are required only in the analysis phase, allowing researchers to bank photo data and process images when image resources are available. In preparation for applicability to large whales, we developed the procedure on small marine mammal subjects, and further adapted it to large targets by taking data sets on inanimate objects such as large vehicles. Photo method variations were explored and tested to optimize data quality in an outdoor setting. The procedure was tested during two North Atlantic right whale (Eubalaena glacialis) stranding events, and 3D reconstructions were created for the carcasses. The reconstructions of the pectoral fins were utilized as a test case for conversion to CAD files and 3D printing of structures of interest.

P3-101 MURPHY, M/S*; SECOR, S/M; DENARDO, D/F; University of Alabama, Arizona State University; *mmurphy11@crimson.ua.edu*

Snakes Must Drink: Meal Consumption does not Improve Hydration State

Water is critical to survival, yet free-standing water is often rare in deserts and seasonally dry environments. Thus, many dry-adapted species utilize either metabolic (that produced from metabolism) or dietary (that found in food) water to meet their hydric needs. It is widely suspected that desert snakes can fulfill their hydric needs solely through dietary water intake. However, food consumption does not improve the hydration state of Gila monsters, *Heloderma suspectum*, a binge-feeding desert lizard. Therefore, we predicted that meal consumption would not improve hydration state in dehydrated western diamond-backed rattlesnakes (*Crotalus atrox*). We found no significant difference in the change in plasma osmolality between moderately dehydrated snakes that consumed a meal and those that did not. In fact, snakes that received a meal reached severe dehydration nine days sooner than snakes that did not receive a meal. Additionally, consuming a meal when severely dehydrated did not reduce plasma osmolality, whereas severely dehydrated snakes provided with water ab libitum returned to a normosmotic state. These results, coupled with previous data from Gila monsters, suggest that carnivorous desert reptiles likely rely on free-standing water to fulfill their hydric needs. Furthermore, preliminary data on the semi-aquatic the diamond-backed watersnake (*Nerodia rhombifer*) adds further evidence of the ineffective use of dietary water to improve hydration.

P1-232 MURPHY, PR*; ROARK, AM; Furman University; *parker.murphy@furman.edu*

Estrogenicity of Compounds Produced by Anemones and their Algal Symbionts

Many cnidarians form a symbiotic relationship with intracellular, photosynthetic algae, whereby host and symbiont exchange nutrients and other vital compounds. We believe that this relationship extends beyond nutritive benefits and that the algae influence the development of their hosts. For example, we previously demonstrated that symbiotic anemones, which harbor symbionts, develop larger gonads than aposymbiotic anemones, which lack symbionts. The mechanism underlying this pattern is unknown. Free floating photosynthetic algae, like more complex plants, have been shown to produce organic compounds such as sterols, saponins, and alkaloids, and many of these compounds agonize metazoan nuclear receptors (NR). Furthermore, NR agonists are bioactive in cnidarians, as treatment with estrogenic compounds increases the rate of asexual reproduction in both anthozoans and hydrozoans. We propose that symbiotic algae influence the development and reproduction of host cnidarians via such NR-mediated signaling pathways. We tested this hypothesis using *Aiptasia pallida* anemones. Our goal was to screen anemone tissue, algal tissue, and anemone culture water for estrogenic NR agonists using a competitive estrogen receptor (ER) binding assay. The assay leveraged three isoforms of teleost estrogen receptors (ERα, $ER\beta_1$, and $ER\beta_2$). We detected estrogenic compounds in multiple sample types. These results will be discussed in a physiological context.

S9-9 MYDLARZ, LD; University of Texas Arlington; *mydlarz@uta.edu*

Insights into coral disease and innate immune signaling using genomic and proteomic approaches

Cnidarians rely on the innate immune defenses based on self/non-self recognition, signaling and effector responses to kill pathogens and heal wounds. Like other invertebrates, the immune system of cnidarians can be classified into several functional components and many of these elements have now been described in various cnidarian model systems. These include pattern recognition receptors, both external and cytosolic, signaling such as NF-kb and prophenoloxidase, effectors such as anti-microbial proteins, and wound repair including apoptosis, autophagy and cellular migration. Specifically corals and the increase in coral disease outbreaks have presented opportunities to examine how immunity functions in directing disease phenotypes. This talk will describe new experiments, approaches and meta-analyses in the Mydlarz lab to elucidate the coral immune response. Several examples will be highlighted that have furthered our knowledge of the various stages of the immune response include the immune response of corals to pathogen associated molecular patterns, immune response to an active infection of white plague and a late stage immune response to a novel disease. Special emphasis will be on linking gene repertoires to the signaling proteins and molecules as well as to cellular activity that lead to disease phenotypes.

P1-271 MYERS, C.R.*; VAZ, D.F.B.; Mount Holyoke College, Virginia Institute of Marine Science, College of William and Mary; *myers22c@mtholyoke.edu*

Myology of the adhesion disc of Snailfishes (Liparidae: Cyclopteroidea)

Several lineages of teleost fishes have evolved ventral adhesive organs that allow adhesion to substrates. The superfamily Cyclopteroidea contains two families with such organs, the Cyclopteridae (lumpsuckers) and the Liparidae (snailfishes). In both families, the adhesive organs are hypothesized to be modifications of the pelvic girdle and fins. Descriptions of the myology of the ventral adhesive disk is lacking in snailfishes. An account of the myology of the adhesive organ can provide insights into how the adhesive organ functions and allows morphological comparisons that should suggest how these structures evolved. This study provides accounts of the myology of the ventral adhesive organ of several species of the genus *Liparis*. Data was obtained by manual dissections and by microCT scanning specimens stained with PMA (phosphomolybdic acid) for soft tissue definition. In Liparidae, the adhesive organ is built on the basipterygium, that form the base of the pelvic girdle. Its two halves articulate with five laterally expanded fin rays and one spine each. The intrinsic musculature of *Liparis* has bifurcated muscle groups present on the dorsal and ventral sides of the basipterygium. On either side, these muscles originate on the dorsal region of the basipterygium and insert on the same side of the dorsal surface of each fin ray. A relatively larger muscle originates on the antero-ventral edge of the basipterygium and inserts on the dorsal side onto the dorsal surface of the first fin ray. This muscle is proposed to be homologous to the muscle abductor profundus pelvicus found in other percomorphs. Comparisons with the adhesive organ of the lumpsucker, *Eumicrotremus orbis*, and with pelvic fins of few species of Cottidae will be presented and discussed.

3-7 NADLER, LE*; ELLIS, HI; NELSON, A; TURNER, AV; WILLIAMS, CL; ØVERLI, Ø; HECHINGER, RF; Norw. Univ. Life Sci., Univ. of San Diego, Univ. of California, San Diego, Univ. of California, San Diego; *lauren.nadler@nmbu.no*

Are Parasites Always Detrimental? Costs of infection to final hosts that forage on prey modified by parasites

Trophically transmitted parasites often adaptively manipulate their intermediate host's phenotype. These phenotypic changes typically increase transmission to the next host in the life cycle, through greater prey (intermediate host) capture by predatory final hosts. Although final hosts will incur some cost from harboring such parasites, mathematical modelling suggests that there can be a net fitness advantage to preying on manipulated food sources when the energy gained from the parasite "delivery service" outweighs the costs of infection. However, little work has quantified the costs of infection to final hosts of parasites that are known manipulators. This study has examined the costs of infection to final hosts of the trematode parasite *Euhaplorchis californiensis* (henceforth referred to as Euha). Euha infects the brains of the California killifish, *Fundulus parvipinnis*, and increases their frequency of conspicuous behaviors, making infected fish 10-30x more likely to be eaten by final host estuarine birds. Euha is a generalist for its final host, theoretically capable of infecting any endotherm that eats infected killifish. As a proxy for estuarine birds, we used lab-reared ducks and chickens that were infected repeatedly for four weeks from ten days post-hatching. In both species, we found no detrimental effects on any trait examined, including growth, skeletal morphology, behavior, hematocrit, immune function, or energy metabolism. This study provides evidence that trophically-transmitted parasites can benefit predatory final hosts by making prey easier to capture, while exerting minimal energetic costs.

P2-17 NAKANISHI, N; University of Arkansas; *nnakanis@uark.edu*

Investigating the developmental regulatory role of the class IV POU/brn-3 gene in a sea anemone

The class IV POU (pou-iv, or brn-3) gene encodes a homeodomain transcription factor that evolved at or near the base of the animal tree. pou-iv genes regulate sensory cell subtype differentiation and maintenance in bilaterian models (e.g. inner ear hair cells and retinal ganglion cells in vertebrates), and their cnidarian ortholog is expressed in a subset of differentiating and differentiated sensory cells in jellyfish, suggestive of a deeply conserved role of POU-IV in regulating sensory cell differentiation. However, mechanistic understanding of how POU-IV regulates neural differentiation and maintenance is wanting in Cnidaria, and thus fundamentally conserved transcriptional control mechanisms underlying these processes remain enigmatic. To address this baseline knowledge gap, I am investigating the molecular mechanisms by which POU-IV specifies and maintains neural subtypes in the sea anemone cnidarian Nematostella vectensis. Preliminary gene expression analyses by in situ hybridization and immunostaining with an antibody against N. vectensis POU-IV show that POU-IV is specifically expressed in neurons in N. vectensis, consistent with the hypothesis that POU-IV plays a role in neural development and maintenance in N. vectensis. I am directly testing this hypothesis by taking a CRISPR-Cas9-mediated gene knockout approach. Comparison of the results of these analyses with existing data from bilaterian models is expected to reveal a deeply conserved mechanism that confers, and maintains, neural subtype identities in animals.

27-4 NAMES, G*; KRAUSE, J; ANGELIER, F; SCHULTZ, E; WINGFIELD, J; Univ. of California, Davis, Univ. of Nevada, Reno, Centre d'Etudes Biologiques de Chizé, CNRS, Kenyon College; *grnames@ucdavis.edu*

Relationships between Avian Malaria and Immunomodulatory Hormones in a Hawaiian Honeycreeper

Invasive species are among the greatest contributors to modern animal extinction. In particular, diseases are invading novel habitats and hosts at unprecedented rates. Avian malaria, introduced to Hawaii in the early 1900s, has contributed to declines of numerous Hawaiian honeycreeper species. The Hawaii Amakihi (*Hemignathus virens*) is the only honeycreeper that has maintained stable populations at low elevations (< 700m), where avian malaria is prevalent. Evidence suggests that low elevation Amakihi populations have evolved tolerance to malaria, but the mechanisms responsible for this tolerance remain unknown. We hypothesized that immunomodulatory hormones play a role in tolerance to avian malaria, thus predicting that hormone levels would differ between low elevation (malaria-exposed) and high elevation (malaria-unexposed) Amakihi. We measured three immunomodulatory hormones, corticosterone (CORT), testosterone (T), and prolactin (PRL), in Amakihi living at low and high elevations. While baseline CORT was consistent across elevation ($p = 0.80$), peak CORT (in response to restraint) was significantly greater in high compared to low elevation males ($p = 0.016$). When considering all sampled males, difference in T across elevation was not detected ($p = 0.58$), but when taking age into account, second years (SYs) at low elevation had lower T compared to SYs at high elevation ($p = 0.016$). Finally, PRL did not vary by elevation ($p = 0.11$), but we found a relationship between PRL and breeding status ($p < 0.001$) and a correlation between PRL and bird condition ($p = 0.0052$). Our results suggest that T and peak CORT may have a correlational relationship with avian malaria, and that these correlations are dependent on age and sex class, respectively.

92-6 NAMIKI , S; ROS , I; ROWELL, W; DE SOUZA, A; DICKINSON, MH; KORFF, WL*; CARD, GM; Howard Hughes Medical Institute, Janelia Research Campus, California Institute of Technology; *korffw@janelia.hhmi.org*

Descending control of flight behavior in flies

Animals exhibit an astonishing array of complex behaviors whose neural underpinnings remain largely unknown. In most animals, the brain affects these behaviors through communication with motor centers in the body through a set of Descending Neurons (DNs) that traverse the neck. We studied the role of DNs on flight control in the fruit fly *Drosophila melanogaster*. Using cell-type specific driver lines we generated that target individual DNs, we leveraged optogenetics, calcium imaging and electrophysiology to interrogate the function of Flight Descending Neurons (FDNs) innervating the wing and haltere neuropils in the ventral nervous system. We found unique FDNs with bilateral pairs and population FDNs that form small groups of cells with nearly identical arbors. One population of FDNs, DNg02, contained up to fifteen pairs of morphologically identical neurons. By systematically activating subsets of these FDNs using CsChrimson, we observed changes in wingbeat amplitude and frequency during tethered flight. Although the wingbeat amplitude was directly proportional to the number of FDNs activated, frequency changes depended on the frequency level prior to activation up to a specific setpoint. These results, as well as calcium imaging, show unilateral activity of these cells in response to visual stimuli and suggests the use of population coding for flight control by the FDNs for modulating not only thrust responses during flight but also turning.

P1-285 NARDUCCI, RE*; HULBERT, RC; BOURQUE, JR; BLOCH, JI; University of Florida/Florida Museum; *rnarducci@flmnh.ufl.edu*

Cranial Armor of the Pleistocene Pampathere Holmesina (Xenarthra, Cingulata, Pampatheriidae)

The skin of cingulates is imbedded with plates of boney osteoderms, sutured together into shields to protect 3 separate areas; the head, body, and tail. Osteoderms vary greatly in shape, number, and arrangement across cingulates. Shields typically disarticulate shortly after death and isolated osteoderms are more commonly recovered from the fossil record. Osteoderms comprising the cranial shield are thinner, more irregular in shape, and poorly sutured together compared to other regions; diminishing preservation potential. Among the extinct group of giant armadillos known as pampatheres, isolated cranial osteoderms are mentioned in the literature, but no complete cranial shield has been described. The Florida Museum houses 9 partial to nearly complete cranial shields of the pampathere, *Holmesina floridanus* and 2 of the larger and younger *Holmesina septentrionalis*. A complete *Holmesina* cranial shield is composed of ~75 osteoderms, and is only slightly longer than wide, bilaterally symmetrical, and widest at post-orbital protuberances, which curve ventrally. Osteoderm shape, number of sides, and thickness varies across the cranial shield, dependent on anatomical position. Compared to extant armadillos, the shield is most similar to that of the euphractines in osteoderm count and shield shape, and differs most from that of *Dasypus*, which exhibit a greater number of osteoderms and narrower shield with a pointed posterior periphery. Great diversity exists in the cranial shield of extinct glyptodonts. They differ from those of *Holmesina* in exhibiting fewer, larger, thicker, and ornate osteoderms comprising broader cranial shields with less pronounced post-orbital protuberances.

P2-254 NARICI , V*; PIRRONE, M; BARNHART, D; MASS, S; SUNY New Paltz ; *nariciv1@hawkmail.newpaltz.edu*

Using Force to Characterize the Efficiency of Ambystomoid Locomotion

Axolotls are ambystomoids that are closely related to the North American tiger salamander. They are a neotenic species and remain aquatic throughout their lives. Rarely, they spontaneously metamorphose and become terrestrial animals. Although metamorphosed axolotls are similar to other terrestrial ambystomoids, there are differences in form and function, which are not well-understood due the rare nature of metamorphosis. Upon casual inspection, metamorphosed axolotls seem to lack the coordination of terrestrial movement that the tiger salamanders possess. Are metamorphosed axolotls less well adapted for terrestrial locomotion? Are there developmental timing windows being missed which account for the differences in form and function? We are interested in the functional morphology that can account for these differences. Our first step has been to compare the force of metamorphosed axolotls and tiger salamanders using compressible force sensors. Specific patterns in their movement were identified and the force was measured. Work was then calculated from the force measurements. Analysis of the data shows higher force and work values for the metamorphosed axolotls, which are indicative of lower efficiency at terrestrial locomotion, compared to the tiger salamanders.

P2-146 NASH, S/B*; RAHMAN, MD/ S; University of Texas Rio Grande Valley ; *sarah.nash01@utrgv.edu*

Consequences of high temperatures on gonadal functions, cellular apoptosis and oxidative stress in the American oyster

Global warming is likely to intensify heat stress in marine and coastal organisms, affecting their development, growth, and reproductive functions. In this study, we performed histological observations on gonadal functions, immunohistochemical analyses of heat shock protein (HSP) and nitrotyrosine protein (NTP, an indicator of reactive nitrogen species, RNS) expressions, in situ TUNEL assay for cellular apoptosis, biochemical analyses of caspase-3/7 activity and protein carbonyl (PC, a measure of reactive oxygen species, ROS) contents, and coelomic fluid (CF, body fluid that regulates physiological functions) pH in the American oyster gonad with various water temperatures. Oysters were placed in six different twenty-gallon aquariums and exposed to control (24oC), medium (28oC), and high (32oC) temperatures under controlled laboratory conditions for one week. Higher temperature significantly decreased the number and diameter of eggs in ovary of female oysters and sperm cell growth, development, and production in male oyster's. CF protein concentrations also declined compared to control temperature (24oC). In contrast, CF pH and HSP expression in gonad increased after heat-exposure, consistent with increased cellular apoptosis. The enhanced apoptosis in gonads of heat-exposed oysters was associated with increased gonad caspase-3/7 activity, PC contents, and NTP expression. Collectively, these results suggest that higher temperatures drastically increase ROS and RNS levels leading to increased cellular apoptosis, which subsequently decline gonadal functions in oyster.

69-3 NASH, CM*; GEORGE, AB; MCCORD, CL; WESTNEAT, MW; University of Chicago, University of Chicago; Chapman University; *cmnash@uchicago.edu*

Functional Biogeography: Patterns of SpatioTemporal Evolution of Biomechanical Traits in the Triggerfishes (Balistidae)

Due to the large variability among habitats and geographic regions, fishes have evolved extraordinary morphological and functional diversity to best utilize different environments. However, the relationships among geographic ranges, ecological processes, patterns of functional trait distributions, and multivariate shape diversity are not well understood. In this study, we aim to examine these complex interactions through an integrative analysis of the spatial and phylogenetic distribution of biomechanical traits associated with feeding and locomotion across a charismatic family of marine fishes, the triggerfishes. Triggerfishes (Balistidae) are a circumtropical family of approximately 42 species that occupy a wide variety of ecological roles, with habitats ranging from complex coral reefs to the vast open ocean and diets ranging from planktivory to durophagy. Previous studies have revealed that triggerfishes have converged on fin and cranial morphologies best suited for specific ecological functions. We integrate detailed multivariate shape data of the body, fins, and jaw linkage mechanics of 27 species with comprehensive georeferenced coordinate data and fine-scale ecological data in order to understand of the distribution of ecologically relevant biomechanical traits among taxon specific biogeographic regions and across the phylogeny. Our results reveal show the relationships between the spatial distribution and evolution of triggerfish biomechanical and morphological diversity among geographic regions and species assemblages. NSF 1541547.

P1-98 NAVARA, KJ*; WROBEL, ER; The University of Georgia; *knavara@uga.edu*

Can birds lay more than one egg in a day? Yes they can!

The time interval between successive eggs in a clutch has been known to vary substantially among species; many species lay at a rate of one egg per day while some wait up to 30 days to lay the next egg in the clutch. For no species have time intervals of less than a day been observed between ovipositions. Our current understanding of avian physiology suggests that laying eggs at intervals shorter than 24h should be physiologically impossible, because ovulation and oviposition are timed according to the light/dark cycle, only a single ovarian follicle should be ready to ovulate on a given day, and more than one egg in the shell gland would likely lead to shell abnormalities. However based on anecdotal accounts of hens that routinely produce two fully formed eggs in one day (termed double ovipositions), we hypothesized that laying hens may exhibit this pattern more often than was previously realized. To test this, we observed a flock of laying hens, monitoring the time of oviposition for each hen on each day using a thermal camera. We found that 13% of hens produced a double oviposition, often producing a second egg within 2.5h of the first, at least once during the observation period. One hen produced double ovipositions multiple times, and one produced 3 eggs in a day. Further, we then monitored a second flock of laying hens and found additional evidence of double ovipositions. Eggs that were part of double ovipositions showed no external shell abnormalities and weighed the same as those that were single ovipositions, suggesting that laying hens can, and do, produce two fully formed eggs within hours of one another. This finding refutes our currently understanding of avian reproductive physiology and calls for additional work on the regulation of ovulation and oviposition, particularly in laying hens.

70-1 NAVON, D*; HATINI, P; ZOGBAUM, L; OLEARCZYK, N; ALBERTSON, RC; University of Massachusetts Amherst; *dnavon@cns.umass.edu*

Genetic architecture of coordinated plastic responses across different traits in African cichlids

Phenotypic plasticity allows organisms to respond quickly to changing environmental conditions, and may influence patterns of future evolution by exposing new variants to selection. However, relatively little is known about the genetic basis of plasticity - e.g., What are the genetic factors that influence the ability to mount a plastic response? Are coordinated plastic responses across anatomical units mediated by many distinct loci or by a few "global" regulators? To address these outstanding questions, we reared a hybrid cichlid mapping population on alternate benthic/pelagic diet regimes, which mimicked natural variation in foraging preference across cichlid species. We documented plasticity for an array of ecologically relevant traits including craniofacial, whole body, pectoral fin, and pharyngeal jaw shapes. We found a notable degree of correlation among traits, which confirms a coordinated plastic response. We next sought to assess the degree of overlap in the genetic control of plasticity. To this end, we scanned the genome for plasticity loci across these distinct traits, and again observed a similar pattern of correlation in the genetic determination of plasticity. In all, our data provide support for the existence of global regulators of plasticity, serve as an important step toward further characterizing the genetic basis of plasticity in cichlids, and provide a list of candidate loci for future functional analyses, including an activin receptor gene that may be key for plasticity in craniofacial, fin, and body musculature.

S12-8 NAYLOR, ER*; HIGHAM, TE; Univ. of California, Riverside; *emily.naylor@email.ucr.edu*

Attachment Beyond the Adhesive System: Assessing the Contribution of Claws in Gecko Clinging and Locomotion

A steadily improving grasp of the morphological and mechanical basis of gecko adhesion continues to inspire innovation and investigation of its adaptive significance. However, the role of claws as an additional, ancestral attachment mode within this diverse clade has largely been overlooked. Empirical assessment of pads and claws, including their employment under ecologically relevant conditions, is needed to better inform evolutionary hypotheses and biomimetic development. As pads are most effective when setal contact is optimized (i.e., smooth surfaces), and claws engage via penetration or interlocking with irregularities (i.e., rough surfaces), geckos with both features may be well equipped to manage a variety of substrates, as seen in some insects. *Thecadactylus rapicauda* occupies various arboreal and artificial substrates and exhibits an adept adhesive system and claws. Using wild- caught individuals (Nouragues Natural Reserve, French Guiana), we evaluated the relative contribution of claws to clinging and locomotion on natural and artificial surfaces: leaves, wood, sandpaper, and acrylic. Clinging performance and locomotor trials were conducted before and after partial claw removal; 3D microtopographical reconstructions from confocal microscopy were used to quantify test surface roughness. As anticipated, clinging force declined post claw removal on substrates with greater 3D surface roughness, including sandpaper and a leaf with tall trichomes. Patterns of foot placement during locomotion (e.g., duty factor, timing of digital hyperextension) appear more complex across substrates of different roughness and incline. Our study advances future attachment inquiries and provides perspective for the potential correlated function and evolution of gecko toe pads and claws.

P2-10 NEBHUT, AN*; WORLEY, CA; SHINKLE, JR; Trinity University, San Antonio; *anebhut@trinity.edu*

Individual Variation in Untreated Schizachyrium scoparium Metrics Used to Quantify Responses to UV-B Radiation

Plants have mechanisms to sense dangerous ultraviolet radiation and regulate their responses to changes in their light environment. In particular, plants exposed to UV-B (280 to 315 nm) display unique responses such as inhibited growth and production of UV-protecting pigments. These responses are the can be either global or tissue specific. Little bluestem (*Schizachyrium scoparium*) were sampled at a field site in Travis County, Texas. We chose 3 minimally invasive methods commonly used to measure plant responses to UV stress: UV absorbance spectra taken from leaf extract pigments, reflectance spectrophotometry of leaves, and leaf chlorophyll and flavonoid content. Results indicate that individual plants maintain different protections from UV radiation including changes in leaf structure and composition from bunch to bunch, even within the same field site (120 m2). For instance, there were significant differences between two bunches four meters apart for absorbance, reflectance, chlorophyll, and flavonoids. The consequence of this variation can be seen by comparing a result to the outcome of modifying the UV environment: the 67.9% decrease in absorbance at 300nm between two untreated bunches eight meters apart is comparable to the 69.5% decrease in absorbance in one bunch after one week's time under a UV-B excluding cellulose acetate filter. However, across 10 bunches many pairs showed no differences or differences in only some parameters. Overall, these results inform the design of further research into plant responses to UV-B radiation by demonstrating the need for large samples including many individuals to ensure that the results are actually a response to the treatment and not natural variation between individual plants.

121-2 NEEL, L*; LOGAN, M; LOSOS, J; MCMILLAN, O; COX, C; ANGILLETTA, M; Arizona State , Smithsonian Tropical Research Institute, Washington Univ, Georgia Southern, Arizona State; *LKNeel@asu.edu*

Environmental heterogeneity, thermoregulatory strategy, and the effects of climate change on ectotherms across latitude

Relative to higher latitude species, tropical ectotherms are thought to be thermal specialists and therefore especially vulnerable to anthropogenic climate change. Nevertheless, most tropical species live in closed forests which promote thermoconformity. Thermoconforming species experience the full range of temporal thermal variation in their habitat, while species in higher latitude, heterogeneous habitats can thermoregulate to achieve narrow body temperature distributions. Thus, while ectotherms living in higher latitudes experience greater annual and diel variation in temperature, they may be thermal specialists relative to tropical forest species. We studied the thermal ecology and physiology of two closely-related species occupying divergent thermal environments: *Anolis sagrei* lives in open habitat in The Bahamas and *Anolis apletophallus* occurs in densely vegetated tropical forest in Panama. We evaluated the extent to which thermoregulatory strategy (thermoconformity versus thermoregulation) was associated with specialization in thermal physiology, and then modeled the effects of climate change on each of these species while explicitly taking behavior into account. We hypothesized that *A. sagrei* in open, thermally heterogeneous habitats may have narrower breadths for physiological performance compared to *A. apletophallus* in the temporally stable tropics, due to differences in thermal opportunity, which may reduce future performance under predicted warming scenarios. We discuss the importance of considering thermoregulatory strategies when predicting the fitness consequences of climate change on ectotherms across latitudes.

P1-225 NEMANI, S G*; EDWARDS, C J; HALL, M W; MARTIN, IV, W R; EVANGELISTA, D J; United States Naval Academy; *m194668@usna.edu*

Affordable Unmanned Aerial Systems (UAS), Sensors, Modular Payloads and Algorithmic Tools for Ecological Study

Ecological and behavioral studies and conservation efforts are often complicated by the need to gather data in remote or inaccessible areas. In military missions, unmanned aerial systems (UAS) have been instrumental in providing remote access and persistent presence. We will discuss an on-going design effort to develop affordable UAS designs, as well as sensors and modular payloads, aimed at supporting science missions. Our designs leverage developments in hobby radio/control and autonomous flight, 3D printing, and rapid prototyping. We consider both fixed-wing and quadrotor designs and will discuss modular payloads, including visible and thermal imaging and automated image processing. The rugged nature of biological field studies and unique challenges help drive design innovations. We will present concept designs and initial prototyping for notional biology and ecology missions: (1) to image and count organisms and/or nests along a shore; (2) to survey an area, field, or stretch of river, repeatedly to identify areas of interest or to assess damage after natural disasters; and (3) to recover a sample from an inaccessible location on an island top or inside a sinkhole. We will also discuss the logistics of training undergraduate engineers as UAS operators (USNA's "School of Drones") and plans to deploy in support of biologists to accomplish science missions. The UAS designs we develop will be made available for science work, and we hope to connect with potential future missions using UAS to support biological studies.

P2-183 NEUROHR, JM*; PAULSON, ET; KINSEY, ST; Univ. of North Carolina Wilmington; *jmn6284@uncw.edu*

Oxidative damage and protein synthesis in red and white muscle of the pinfish, Lagodon rhomboides

An unavoidable consequence of aerobic metabolism is the production of reactive oxygen species (ROS). While ROS are important molecular signals in cells, excess ROS cause damage to cellular components such as lipids and proteins. While there is general agreement that mitochondria are the primary sources of ROS, it is not clear how variation in mitochondrial density or metabolic rate among tissues influences ROS-induced damage and rates of protein synthesis. Fish skeletal muscle is comprised of highly aerobic red muscle and highly anaerobic white muscle, offering an excellent model system in which to evaluate the role of tissue aerobic capacity on ROS-induced damage. The present study characterizes protein and lipid oxidative damage, as well as markers of protein degradation and measurements of protein synthesis rates, in red and white muscle of the pinfish, *Lagodon rhomboides*. Red muscle had a greater mitochondrial volume density and had more oxidative damage than white muscle, including elevated protein carbonylation and lipid peroxidation. Protein degradation in muscle occurs via the lysosomal-autophagy or ubiquitin-proteasome pathways and has been shown to be tissue dependent. Lysosomal degradation markers and autophagosome volume density were greater in white muscle, while ubiquitin expression and 20S proteasome activity were significantly greater in red muscle. However, ubiquitin ligase expression was significantly higher in white muscle. Red muscle also had a higher basal metabolic rate and higher rates of protein synthesis, presumably due to the higher mitochondrial volume density and the associated increase in oxidative damage. Together these results support the concept that a consequence of an elevated aerobic capacity is greater costs associated with protein synthesis.

93-4 NEVELN, ID*; DALLMANN, CJ; SPONBERG, S; Georgia Institute of Technology, Bielefeld University; *ineveln2@gmail.com*
When Time is Scarce, Timing is Almost Everything: a Comparative Analysis of Fast vs. Slow Insect Locomotor Control
A cockroach may be easy to spot on your kitchen floor, but their quickness makes them hard to catch. In contrast, a stick insect will not easily escape once detected. Locomotion of these insects has long been compared due to their divergent adaptations of speed range and morphology. Both have homologous muscles, motor units, sensors, and nervous centers that they use to control their six legs. However, strategies of control are likely different. Specifically, spike rate codes of motor neurons have limited information bandwidth for fast behaviors, and a spike timing code may be necessary. Here we investigate how the encoding of muscle activity differs between the two. In both animals, we compared activity from similar muscles in the coxa that extend the trochanter joint to the kinematic output of the leg. At their preferred speeds, the stride frequency of cockroaches is about five to ten times faster than that of stick insects. Therefore, this motor unit spikes less often per stride in the cockroach than the stick insect. Even though this discrepancy means the stick insect motor unit has higher potential information capacity, similar amounts of mutual information are shared between the motor unit and leg movement in the cockroach and stick insect. Moreover, when timing of motor unit activity is taken into account, encoded information triples in the cockroach and only doubles in the stick insect. This comparison indicates that during fast locomotion, the timing of muscle activity becomes more important for control compared to slow locomotion, although both strategies are important in each case.

137-7 NEWHOUSE, DJ*; GONSER, RA; BALAKRISHNAN, CN; East Carolina University, Indiana State University; *newhoused12@students.ecu.edu*
Impacts of parental genotypes on nestling gene expression
Parents can have profound epigenetic effects on offspring fitness. Little, however, is known about the epigenetic impacts of parental care variation in offspring and how such variation may interact with offspring genotype in natural systems. The white-throated sparrow (*Zonotrichia albicollis*, WTSP) provides an ideal system to investigate the epigenetic effects of parental care in offspring. WTSPs exist in two genetic morphs, tan and white, controlled by a chromosomal inversion. Morphs mate disassortatively, resulting in distinct parental care types: biparental care (tan male x white female) and female-biased care (white male x tan female). Both parental care types produce tan and white morph offspring, offering an opportunity to study how offspring morph interacts with parental care variation. To investigate parental care impacts in WTSP nestlings, we performed RNA-seq on WTSP nestlings experiencing the two parental care types. We find 881 genes differentially expressed (DE) between the two nest types and seven gene co-expression modules correlated with parental care. These modules and DE genes up-regulated in female-biased nests primarily function in metabolic, catabolic, and stress related pathways resulting from the overrepresentation of stress response and proteolysis genes. Nestlings also exhibit morph specific gene expression, driven by both innate immunity genes and strong co-expression of genes located in the chromosomal inversion. However, there is no apparent difference between morphs in their response to parental genotypes. We have demonstrated that differences in parental genotypes alter nestling metabolism and stress. This difference is likely driven by variation in parental care.

35-3 NEWMAN, AEM; University of Guelph; *newman01@uoguelph.ca*
Is it what's on the inside, or the outside, that counts? Effects of season and urbanization on stress physiology and the microbiome.
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, (*Sciurus carolinensis*), 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 across seasons. 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 provides an opportunity to understand how wildlife cope with, adapt to, or even exploit novel environments.

P3-51 NGO, T*; KASOJU, VT; FORD, MP; SANTHANAKRISHNAN, A; Oklahoma State University; *askrish@okstate.edu*
Aerodynamic effects of varying pause durations during clap and fling
The smallest flying insects such as thrips and fairyflies have body lengths under 1 mm and operate at very low Reynolds number (Re) on the order of 10 or lower. Flapping flight is challenged in these size scales on account of large viscous forces on the wings. These insects often show unique biomechanical adaptations that include: wings with long bristles at the fringes, and the use of clap and fling wing-wing interaction to maximize wing amplitude. Ellington (1975) observed that the wings of the chalcid wasp *Encarsia* remain clapped (following end of the upstroke) for 20-25% of the wingbeat cycle. It is not clear if there is an inherent aerodynamic advantage associated with this pause time before the onset of downstroke via fling. In this study, we examined aerodynamic effects of varying pause duration using physical models of bristled wings inspired by biological data. A robotic model mimicking clap and fling motion was used to experimentally test different pause times. Non-dimensional lift and drag coefficients were calculated from strain gauge measurements. Peak lift coefficients in fling increased with increasing pause duration, whereas drag coefficients were nearly unchanged. We will present the effects of varying pause duration on chordwise flow structures.

P1-116 NGUYEN, TC*; SALTZMAN, W; University of California, Riverside; *tnguy240@ucr.edu*

Offspring Discrimination by Mothers and Fathers in a Biparental Mammal

The ability to differentiate between kin and non-kin may confer fitness benefits such as altruism or inbreeding avoidance. In parental care-giving species, parents may also benefit from the ability to discriminate offspring between unrelated infants or juveniles to ensure that the appropriate animals are receiving care. Sex differences in offspring discrimination ability may arise if parental behaviors and their underlying mechanisms differ between males and females of a given species. For example, unique to mammals, mothers must gestate and produce milk while fathers do not. Consequently, mammalian mothers experience different hormone changes than fathers, even if the two parents provide otherwise equal care. Thus, we hypothesized that mammalian mothers and fathers may differ in offspring discrimination. We tested this hypothesis in the monogamous, bi-parental California mouse (*Peromyscus californicus*). At four different time points during the postpartum period (PPD 3, 7, 16, and 28), each parent was housed individually and allowed to interact with two mesh balls, one containing one of its own pups and the other containing an unrelated, age-matched pup, for 10 minutes. We compared behavioral responses to the pups, including the duration of time that each animal spent in proximity to each ball, the number of bouts and latency to approach each ball, and the first and second ball approached, between mothers and fathers, finding no significant difference between the sexes. We further examined possible longitudinal changes in offspring discrimination within individual parents, again finding no significant changes over time. Therefore, we found no evidence for sex-differences in offspring discrimination in the California mouse.

96-5 NGUYEN, K.H.*; ROHR, J.R.; GEMMELL, B.J.; University of South Florida; *knguyen63@mail.usf.edu*

Examining the effects of temperature and viscosity on miracidial and cercarial movement of Schistosoma mansoni

Schistosoma, a family of trematodes that causes human schistosomiasis, have aquatic miracidial and cercarial life stages that depend on a fixed energy reserve to swim and locate intermediate snail hosts and humans, respectively. As small, ectothermic swimmers, these trematodes are likely affected by changes in water temperature and viscosity. However, their modes of locomotion differ; miracidia use cilia while cercariae use a forked tail. Thus, there is a need to quantify the effects of temperature gradients on miracidial and cercarial movement. We used a high-speed camera to quantify the crossed effects of temperature (10°C, 20°C, 30°C) and viscosity. We investigated the effects of temperature and viscosity independently by adding methylcellulose (MC), which maintained a viscosity of 10°C regardless of temperature. We quantified swimming mechanics of miracidia and cercariae of *Schistosoma mansoni* and results show a positive effect of temperature on cercarial tail beat frequency, cercarial speed, and miracidial speed. High viscosity significantly reduced cercarial tail beat frequency and speed, but not miracidial speed between 20 and 30°C. There were positive interactions between temperature and viscosity for cercarial tail beat frequency and speed, but not miracidial speed. Although high viscosity decreased miracidial speed, we found that colder temperatures allow miracidia to move with a lower cost of transport. That is, miracidia travel farther at 10°C than 30°C and thus have a higher probability of encountering a snail host. Conversely, cercariae had poor swimming performance at 10°C and did not travel far. Because miracidia emerge earlier in the year when water temperatures are cooler, our findings provide an explanation for such different body morphologies.

134-2 NICHOLSON, DJ*; LOGAN, ML; COX, C; CHUNG, A; DEGON, Z; DUBOIS, M; NEEL, L; CURLIS, JD; MCMILLAN, WO; GARNER, T; KNELL, RJ; Queen Mary University London; Zoological Society of London; Smithsonian Tropical Research Institute, Smithsonian Tropical Research Institute , Georgia Southern University , Georgia Southern University , Northeastern Univeristy, Arizona State University , Smithsonian Tropical Research Institute, Zoological Society of London, Queen Mary University London; *d.nicholson@qmul.ac.uk*

Natural Selection on Morphology in a Tropical Lizard After a Rapid Shift in Habitat Structure

The Earth's environment is rapidly changing, and this may have dire consequences for the world's biota. When environments change rapidly, mean phenotypes in a population become mismatched with local fitness optima. This mismatch can drive an increase in the strength, and form, of selection on traits linked with fitness. There is a well-established relationship between the biomechanics of lizard morphological traits and habitat structure. Previous studies on lizards have found that longer limbs lead to greater performance on broader perches, while larger toe-pads are favored at higher perch heights. Using a tropical lizard system, we predicted that lizards with longer hind limbs and larger toe pads would be favored on islands with broader perches (larger trees). We transplanted approximately four hundred uniquely-marked slender anoles (*A. apletophallus*) from a single source population to six small islands in Lake Gatun, Panama. These islands differ in habitat structure from each other and from mainland Panama. We conducted mark-recapture over the breeding season in both the first (parental population) and second (F1) generations to estimate viability selection and the overall strength and form of selection in each of these populations. We discuss our results in the context of the role of contemporary evolution in mediating the responses of populations to rapid environmental change.

P2-42 NICKLES, KR*; WEBB, JF; University of Rhode Island; *krnickles@uri.edu*

Does Habitat Predict Lateral Line Morphology Among Species of Neon Gobies (Genus Elacatinus)?

Gobies (Family Gobiidae, the largest family of marine fishes) have a complex mechanosensory lateral line (LL) system comprised of reduced cranial and trunk canals and a proliferation of small superficial neuromasts (SNs), which are perched on the tips of papillae ("sensory papillae"; bump-like extensions of the skin) that occur in linear series. The LL system in *Elacatinus lori*, a sponge-dwelling goby from Belizean coral reefs is composed of a moderate number of SNs (~300 on one side of the head, trunk and tail) when compared to other gobies described in the literature (which may have 1000's of SNs). The genus *Elacatinus* (21 species), found exclusively on coral reefs, is divided into three clades: a Pacific species (basal clade), coral-dwelling cleaner gobies, and sponge-dwelling planktivorous gobies. The large tube sponges in which the sponge-dwelling gobies live produce a constant flow of water within the lumen, where the gobies reside, creating a unidirectional flow stimulus to which the fish are continuously exposed. In contrast, different sorts of environmental flows are experienced by the coral-dwelling gobies. Using SEM, we tested the hypothesis that SN number, distribution, and papilla length in sponge-dwelling *Elacatinus* species (including *E. lori*) are different from those in coral-dwelling *Elacatinus* species; *Tigrigobius*, its sister group, was used as an outgroup. We predicted that sponge-dwelling gobies have fewer SNs and/or shorter papillae than coral-dwelling gobies, which would reduce overstimulation of the SNs that may occur under the constant flow conditions experienced within their host sponges. Funded by NSF grant 1459224 to JFW.

71-9 NIEDERHAUSER, JM*; ZIADI, MP; BLAKELY, B; ANDERSON, RC; Florida Atlantic University; *jniederhause2015@fau.edu*

Spatial pattern of song sharing in Bachman's sparrows

Song sharing is common among male songbirds, but the amount of song sharing between individuals varies depending on the geographical distance between territories. These variations are due to differences in dispersal distances combined with specific song learning periods. Thus, comparing spatial patterns of song sharing allows us to infer song learning strategies and dispersal behavior for even the rarest or most secretive species. Song learning and dispersal are unknown for the Near Threatened Bachman's sparrow (*Peucaea aestivalis*), most likely because it spends much of its life hidden in the understory of pine flatwoods and prairies. Our objective was to compare the number of songs shared among male Bachman's sparrows to understand broad patterns of song development and dispersal. From 2016 to 2018, we recorded adult male sparrows using targeted recording and long-term acoustic recorders, and we marked their locations. We determined their repertoires using a program developed in Matlab, and compared repertoires between males by visually comparing song spectrograms. Song sharing is greater at closer distances, especially for neighbors, and then declines at greater distances. These data suggest that Bachman's sparrows are age-restricted learners, and that they attempt short dispersal distances but will disperse farther if suitable territories are not available. By understanding how these imperiled songbirds disperse, we can make better decisions about conserving their populations.

P1-252 NIELSEN, SV; Florida Museum of Natural History; *stunie@gmail.com*

Multilocus phylogenetics in a widespread African anuran lineage (Brevicipitidae: Breviceps) reveals patterns of diversity reflecting geoclimatic change.

In order to assess the influence of geomorphology and climatic shifts on species diversification in sub-Saharan Africa, I reconstructed the pattern and timing of phylogenetic relationships of rain frogs (Brevicipitidae: *Breviceps*). I generated multi-locus sequence data and then reconstructed phylogenetic relationships and locus-specific networks, inferred dates of divergence among ingroup lineages, and finally used niche modeling to identify possible adaptive divergence. I found that *Breviceps* is monophyletic and comprised of two major, largely allopatric subclades. Diversity within each subclade is concentrated in two areas with contrasting geologic and climatic histories: the arid/semiarid winter rainfall zone in the southwestern Cape, and the semitropical East Coast that receives predominantly summer rainfall. Recognized species diversity in the Cape (based on phenotypic variation) is consistent with observed genetic patterns, whereas the East Coast is shown to harbor unexpectedly high genetic diversity and up to seven putative, cryptic species. Niche models show significant overlap between closely related species. Dating analyses indicate that diversification of *Breviceps* occurred rapidly within the Miocene, with only a moderate decline over the Plio-Pleistocene, suggesting that this process might be slowed but ongoing. I suggest that a combination of two models, a landscape barrier model and climate fluctuation model, can explain patterns of diversification in *Breviceps*, and Miocene epeirogenic events and climatic shifts may have had a considerable influence on contemporary patterns of biodiversity. Topographic complexity and relative geoclimatic stability in the East have promoted cryptic diversification in allopatry, and this area clearly harbors numerous undescribed taxa and is in need of more detailed biotic investigation.

P3-117 NIEVES, NA*; ARNER, A; TOBLER, M; BARTS, N; Kansas State University, Penn State University; *nichole27@ksu.edu*

Reactive oxygen species and their role in H2S toxicity in Poecilia mexicana

Extreme environments are characterized by physiochemical stressors that adversely affect biological processes within organisms. Organisms that inhabit these environments have evolved physiological adaptations that allow them maintain function in the presence of stressors. *Poecilia mexicana*, an extremophile fish that inhabits hydrogen sulfide (H2S)-rich environments, is an ideal system to study how organisms modify physiological processes in response to an environmental stressor. H2S is a naturally occurring toxin in these springs that reversibly binds to cytochrome c oxidase (COX) in the mitochondrial respiratory chain, inhibiting aerobic ATP production. COX is normally responsible for capturing the reactive oxygen species (ROS), which are capable of causing cellular damage. In the presence of H2S, however, COX is incapable of accepting electrons, ultimately resulting in increased production of ROS. Some sulfide-tolerant populations of *P. mexicana* possess a modified COX that allow them to maintain ATP production and maintain cellular function in the presence of H2S, while other sulfide-tolerant - and sulfide-intolerant - populations and an additional population do not. We predict that upon exposure to environmental H2S, concentration of reactive oxygen species should be higher in fish that lack a sulfide-tolerant modified COX. Additionally, we predict that lipid peroxidation, damage used to assess the negative effects of ROS on cells should also be higher in these same populations. Preliminary data shows that there is a significant effect of H2S exposure on ROS production in the liver, but not brain or gill. The data collected in this project will provide further understanding on the role of ROS in H2S toxicity.

101-8 NIITEPõLD, K*; PARRY, HA; KAVAZIS, AN; HOOD, WR; Auburn University; *kzn0023@auburn.edu*

Starvation reduces mitochondrial function in the monarch butterfly

Mitochondrial function is key to health, performance, and fitness. Wild animals are exposed to changing environmental conditions which may result in stress to the individual. One such situation is reduced food availability. Reduced food availability limits an animal's ability to support energetically expensive processes such as movement, reproduction, and somatic maintenance. While modest dietary restriction often has positive effects on health in mammals, invertebrates do not necessarily show the same response. Previous work on butterflies has demonstrated that dietary restriction reduces reproductive output and does not extend lifespan. Metabolic flight capacity however appears to be conserved under stressful conditions. Here, we examined the effects of starvation on mitochondrial respiration in a long-distance migrant, the North American monarch butterfly (*Danaus plexippus*). The monarch is an iconic species, yet its populations have been in sharp decline in recent years. We used reproductively active summer-generation monarchs that were subjected to 48 h of starvation. We found that starvation led to a lower respiratory control ratio, indicating reduced mitochondrial performance. The effect was mainly due to starved individuals having higher state 4 respiration, reflecting the increased uncoupling of the resting state when available ADP has been converted into ATP. The result suggests that a relatively short period of starvation can have detrimental effects of mitochondrial performance and possibly flight performance and fitness. Compromised mitochondrial function may act as a mechanistic link between reduced availability of nectar-providing flowers in agricultural landscapes and decreasing monarch populations across North America.

S11-3 NIKLAS, Karl J; Cornell University, Ithaca, NY; *kjn2@cornell.edu*

Biophysical Effects on the Scaling of Plant Ontogeny

Physical laws influence the ability of organisms to exchange energy and mass with their external environments, which in the case of plants is influenced by the size and spatiotemporal display of surface area. In turn, energy-mass exchange rates affect the consumption of resources and thus plant growth and competitiveness. Representative physical laws and processes are reviewed, and empirical data and computer models are used to elaborate on how energy-mass exchange rates, growth, and competitiveness are interconnected. This review shows that biophysical constraints on energy-mass exchange rates significantly influence plant growth and plant-plant competition, while simultaneously also providing opportunities for adaptation and species coexistence.

94-5 NIKOLAKIS, ZL*; SCHIELD, DR; ORTON, RW; ROW, KR; SMITH, CF; MEIK, JM; WATSON, J; MACKESSY, SP; CASTOE, TA; University of Texas at Arlington, University of Northern Colorado, University of North Texas; *zachary.nikolakis@mavs.uta.edu*

Genomic perspective of body size evolution in a rattlesnake complex

Identifying the genomic underpinnings of quantitative characters provides unique opportunities to explore the evolution of complex traits, and whether variation in such traits are driven by unique or convergent molecular changes. The western rattlesnake species complex (*Crotalus viridis - C. oreganus*) represents an excellent model system for studying the evolution of body size across different lineages because there are multiple non-sister lineages that have evolved significantly smaller body sizes. Here we aim to characterize the genomic architecture of body size variation in this group by leveraging population genomic RADseq data across all major lineages of the species complex and a chromosome-level genome assembly of the prairie rattlesnake (*C. viridis*). We use these data to test for signatures of positive selection within previously identified candidate loci that have been linked to body size variation across vertebrates, including insulin-like growth factor (IGF) and bone morphogenetic protein (BMP) signaling. Results from this study provide insight into the evolution of complex traits in multiple lineages. These results have implications for understanding the degree of canalization of growth pathways in natural populations of vertebrates.

P1-57 NIXON, B*; UYANIK , I; YANG, Y; COWAN, NJ ; Johns Hopkins University; *bnixon5387@gmail.com*

Sensory salience affects sensorimotor delay in the tracking response of the glass knifefish

How do sensorimotor computations change in relation to modulations in the salience of sensory information? To address this question, we examined how the refuge-tracking response of the weakly electric glass knifefish *Eigenmannia virescens* changes as a function of electrosensory and visual salience. Our system commanded a refuge to follow a pseudo-random input signal and measured the resulting fish motion. Electrosensory salience was modulated by changing the conductivity of the water, and visual salience was modulated with a light switch. In the light, electrosensory salience had little effect on the input-output response, but in the dark, the phase lag of the tracking response increased with increasing conductivity (i.e., decreasing electrosensory salience). This suggests that the nervous system takes more time to integrate sensory information for control in a manner similar to luminance-dependent tracking in crepuscular moths (Sponberg et al., 2015). We fit these data using the McRuer Crossover Model, a parsimonious model developed to explain visuomotor control in humans. This model captured the salience-dependent change in phase lag with a commensurate change in the time delay parameter with negligible change to other model parameters. More experiments are needed to test the generality of these results.

P2-20 NOLTE, P*; SMITH, FW; Hope College, University of North Florida; *paula.nolte@hope.edu*

Expression Patterns of Gut Genes During Development in Tardigrades

The compact body plan of tardigrades evolved through the loss of several body segments. The metazoan gut is an unsegmented structure divided into foregut, midgut and hindgut regions. Because the gut is an unsegmented structure, we hypothesized that the loss of body segments in tardigrades did not coincide with a loss of a region of the gut. To test this hypothesis, we analyzed three genes that control gut development during embryogenesis in other animals, in the tardigrade *Hypsibius exemplaris*. These genes are *forkhead*, a marker of foregut and hindgut identity; *gata-1/2/3*, an additional marker of foregut identity; and *gata-4/5/6*, a marker of midgut identity. We predicted that these genes would exhibit regionalized expression patterns in the developing tardigrade gut, as they do in other animals. We identified orthologs of these genes in the genome of *H. exemplaris*. Gene expression patterns were visualized using in-situ hybridization during a late embryonic period. *Forkhead* was expressed in an anterior and posterior region of the developing gut in *H. exemplaris* embryos, suggesting that foregut and hindgut regions are retained in tardigrades. However, *gata-1/2/3* was not expressed in the gut, which challenges the retention of foregut identity in tardigrades. Future studies will determine whether *gata-1/2/3* is co-expressed with *forkhead* in an anterior region of the gut during earlier stages of gut development, as predicted if the foregut region is retained by tardigrades, and whether *gata-4/5/6* is expressed in a middle region of the developing gut, as predicted if the midgut region is retained by tardigrades.

4-3 NOONAN, K.R.*; CHILDRESS, M.J.; Clemson University; *noonan2@g.clemson.edu*

Influence of physical structure and live coral cover on coral reef fish community composition and habitat associations in a rapidly changing reef environment

Coral reefs provide essential habitat for thousands of species, supporting much of Florida's economies. Unfortunately, coral reefs are transitioning from structurally-complex, coral-dominated communities to relatively-flat, macroalgae-dominated community, triggering a loss in biodiversity and ecosystem function. Therefore, understanding the relationship between physical structure and biotic composition of coral ecosystems to reef fish diversity and how these communities respond to disturbance events like hurricanes and disease outbreaks is crucial for future reef management strategies. We surveyed reef fish and benthic community structure on reefs in the middle Florida Keys, before and after a major hurricane and coral disease outbreak. Total reef fish abundance and species richness did not change despite significant changes in relative cover of coral, algae, sponge, and soft corals. Herbivores decreased with decreasing algal cover, while omnivores and predators increased with increasing ledges. Neon gobies decreased with decreasing coral cover and shifted to using sponges and sea fans as cleaning stations. This research suggests that reef fish communities are robust to changes in physical structure and substrate cover, but substrate associated species are most sensitive to a rapidly changing reef environment.

P2-277.5 NOORDSIJ, LC*; BELFIORE , ; University of Tampa ; *lindseynoordsij@gmail.com*

Comparative Genomics of Four Mustelid Species: Analysis of LIF gene and its Role in Embryonic Diapause

North American river otters (*Lontra canadensis*) inhabit the second largest latitudinal range of any otter species, from boreal Canada to southern Mexico. Restricted mating and birthing periods are due to seasonal limits. Embryonic diapause, a process which delays the implantation of the blastocyst into the mother's uterus, allows the embryo to rest in a dormant stage until about 40 days before the optimal birth season. Leukemia Inhibiting Factor (LIF), a is an interleukin 6 class cytokine, is a candidate gene involved in the regulation of implantation because it controls cell differentiation and proliferation in the embryo. Here we compare genomic libraries generated by paired-end Illumina TM sequencing at approximately 30X coverage from the North American river otter, the Eurasian otter (*Lutra lutra*), the African clawless otter (*Aonyx capensis*), and the American mink (*Neovison vison*). The African clawless otter and the Eurasian otter do not undergo delayed implantation, while the mink, a member of the same family, but separate subfamily does undergo a limited implantation delay. The domesticated form of the European polecat (*Mustela putorius*), or the ferret, is used as a reference genome. Once we have a draft annotation for these four species, we will be able to compare LIF across dispausing and non-diapausing mustelids.

P1-253 NORDHEIM, C.L.*; RICE, S.A.; DETMERING, S.E.; MCMAHON, T.A.; The University of Tampa; *caitlin.nordheim@spartans.ut.edu*

Growth Rates and Morphology Found in Four Strains of Batrachochytrium dendrobatidis Isolated from Around the World

Batrachochytrium dendrobatidis (Bd) is a contagious pathogenic fungus that has caused amphibian decline worldwide. This is a well-studied species but little is known about the differences in fungal morphology among the Bd strains. Here, we compared the morphology of four virulent strains of Bd, one isolated from amphibians in California, one from Louisiana and two different strains from Panama. The strains were imaged using a scanning electron microscope and we compared the diameter of infectious zoospores, the diameter of the zoosporangia, and the number and size of zoospore discharge tubules found on the zoosporangia. We also grew strains in culture and examined zoospore and zoosporangia production over time. We found that one of the Panama strains zoospores and zoosporangia were larger in diameter ($p < 0.0001$, for both) and had more discharge tubules per zoosporangium compared to the other strains. There were no differences between the strains in respect to the size of the discharge tubules. We also found that the strains differed in zoospore, but not zoosporangia, production in culture ($p = 0.0002$ and $p = 0.6$, respectively). Therefore, one of the Panama strains may be able to grow faster, potentially altering pathogen virulence. Bd is found globally and in laboratory experiments infections are often compared to one another, this morphology and growth information helps us better understand infection dynamics and strain virulence.

P1-190 NORTH , HA*; RAJAMOHAN, A; BOWSHER, JH; North Dakota State University, Edward T. Shafer Agricultural Research Center, USDA, North Dakota State University ; *Heather.ann@ndsu.edu*

Genotoxicity assesment of agrochemicals on honey bee spermatozoa using the TUNEL assay

Agrochemicals and their widespread use are among the suspected reasons for pollinator decline. Some evidence suggests that pesticides are reducing reproductive fitness among bees. Few studies have investigated the contraceptive effects of agrochemicals on spermatozoa. Of special concern is whether agrochemicals impact drone sperm quality, in terms of genotoxicity, having direct or indirect effects on the DNA. Even the slightest changes in spermatozoa can have large impacts on colony health making spermatozoa a reliable biomarker for xenobiotics in the environment. The readily available spermatozoa make them an accessible way to measure the reproductive impacts of agrochemicals found in gathered resources (i.e. pollen and nectar). It is unclear how these stored contaminated resources might affect nest mates, such as drones, who don't actively forage for these resources. Furthermore, how these contaminated resources affect nest mates through all stages of development. To investigate this, we use terminal deoxyribonucleotidyl transferase (TDT)- mediated dUTP nick end labeling (TUNEL) assay as a measure of genotoxicity for spermatozoa. Honey bee spermatozoa were exposed to the agrochemicals Imidacloprid, Thiamethoxam, Clothianidin and Glyphosate. Preliminary results suggest this is an accurate and reliable assay to measure any DNA damage agrochemicals have on spermatozoa. Thus, the purpose of this study is to assess the reproductive impacts agrochemicals have on drones, through direct exposure to agrochemicals and indirect exposure using spermatozoa as a biomarker for these agrochemicals and the effect they have on pollinator decline.

58-7 NOTAR, JC*; JOHNSEN, S; Duke University;
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Sea Urchin Vision in Featureless vs. Spatially Complex Environments

Several species of sea urchin that inhabit spatially complex environments like kelp forests and coral reefs are known to have spatial vision, with acuities ranging from 10° to 33°. Researchers have proposed that these urchins use this relatively poor vision to find shelter from diurnal predators in dark crevices. However, whether sea urchin species that inhabit flat, sandy areas also have spatial vision is unknown. Such habitats are much less spatially complex and rarely offer dark places in which to shelter. Testing urchin species from these habitats can help us understand whether vision is widespread among the urchins or is only present in species that inhabit environments that offer spatial complexity. Three sandy flat-dwelling species, *Lytechinus pictus*, *L. variegatus*, and *Arbacia punctulata* (all n=30) were tested for spatial vision with an orientation experiment. Animals were placed in the center of a round, featureless tank illuminated from above, with a black target of angular size 9°, 25°, or 35° on the wall. Each urchin's movement relative to the target was observed. None of the species of urchin responded to the targets, but some did respond to the visual cue of a researcher. When urchins were moved from their dark adaption chamber to the experimental tank in the light, the animals moved away from the researcher. When urchins were moved to the experimental tank in darkness, however, the animals moved randomly. This suggests that shelter-seeking cues are not important to urchin species in flat, sandy environments, but that visual stimuli may elicit other behavioral responses.

26-4 NOVARRO, AJ; Swarthmore College;
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Widespread and Misunderstood: An Integrative Approach to Thermal Ecology in the Eastern Red-Backed Salamander

The eastern red-backed salamander (*Plethodon cinereus*) is the most widely distributed *Plethodon* species, extending farther north than any other lungless salamander. This species' geographic distribution raises two major questions: How does *P. cinereus* thrive across a wide range of temperatures, and does it possess thermal adaptations that will buffer the ecological consequences of climate change? To explore these questions, I first examined the effects of elevated temperature on metabolic hormone release rates and physiological performance across a latitudinal population gradient. Second, I performed a study to disentangle the environmental and evolutionary drivers of thermal limits across the geographic range of *P. cinereus*. Finally, I combined laboratory experiments, field observations, and population models to explore the role of behavioral thermoregulation in shaping physiological performance. By considering multiple physiological metrics and sampling a large geographic area, I have identified several behavioral and physiological traits that promote performance, and likely fitness, across a wide range of temperatures in this species. Importantly, individuals collected from warmer localities possessed behaviors for coping with the energetic demands of elevated temperatures, whereas those from cooler localities did not. Further, I found evidence that population- and clade-variation in thermal traits will affect population responses to climate change. Together, these results highlight the importance of considering multiple physiological metrics and sampling large geographic areas to understand species' abundance and distributions, and to assess species' vulnerability to climate change.

48-1 NOWICKI, S*; DUBOIS, AL; PETERS, S; RIVERA-CÁCERES, KD; SEARCY, WA; Duke University, Durham, NC, University of Miami, Coral Gables, FL;
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Song is not a reliable signal of general cognitive ability in a songbird

Learned aspects of song have been shown to affect female mating preferences in a number of species of songbirds, including swamp sparrows (*Melospiza georgiana*). One explanation for why female songbirds attend to learned song features is that these signal attributes may convey reliable information about the cognitive abilities of males. This idea is based on the fact that brain development—and therefore song learning and the expression of other cognitive abilities—should all be affected during development by the same stressors, in accord with the "developmental stress hypothesis." We tested whether song is a signal of cognitive ability by relating five measures of song quality to five measures of cognitive performance in a cohort of 49 adult male swamp sparrows whose songs were recorded in the wild and who were then brought into captivity for cognitive testing. The five song measures are repertoire size, mean and minimum vocal deviation (measures of vocal performance), and mean and maximum typicality (measures of song learning). Cognitive performance was measured as the speed with which five cognitive tasks were mastered: a novel foraging task, a color association, a color reversal, a spatial learning problem, and a detour-reaching test. In general linear mixed models controlling for neophobia, none of the song measures predicted any of the cognitive performance measures. Thus, our results do not support the hypothesis that song attributes provide a reliable signal of general cognition in swamp sparrows.

P1-77 NSANGOU, AA*; STAAB, KL; Mcdaniel college, Mcdaniel college ; *aan004@mcdaniel.edu*

Pre-and post-natal development of the lower jaw in two live bearing poeciliid species.

Most larval fish species must begin feeding upon hatching, but livebearing species such as the mosquitofish, *Gambusia affinis*, and mollies,*Poecilia spp.*, develop the feeding apparatus before the need to feed.These two closely-related species have different lower jaw morphologies where *Poecilia spp.* possess an extra joint between the dentary and angular-articular bones,the intramandibular joint (IMJ).The IMJ evolved independently in multiple fish lineages, and in *Poecilia spp.*, has been shown to play a pivotal role in scraping food from substrates, allowing the lower jaw to extend forward when it comes in contact with a food source. In this study, we cleared and stained ontogenetic series of *Gambusia affinis* and *Poecilia spp.* (*mexicana and sphenops*) to determine how the differing lower jaw morphologies develop, in order to make hypotheses about how the IMJ might have evolved in this lineage. Specifically, we establish the onset of lower jaw elements-the dentary, anguloarticular, and Meckel's cartilage (MC)- and compare the allometric growth of the MC between species. We also compare pre-natal and post-natal growth of the lower jaw elements to gain a better understanding of how viviparity affects trait development.

73-6 NUÑEZ, CMV*; RUBENSTEIN, DI; Iowa State University, Princeton University; *nunezcmv@iastate.edu*

Mother-infant communication in feral horses (Equus caballus): what are they saying, why are they saying it, and what might it tell us about the mammalian juvenile stage?

Much of the research regarding mother-offspring communication has focused on individual recognition between mother and offspring and its role in subsequent bond formation. It remains unclear, however, if mothers and offspring utilize auditory communication for the same purposes or under the same conditions throughout the juvenile stage, particularly after social connections have been sufficiently established. Moreover, despite its critical role in mother-offspring bond formation, research explicitly linking mother-infant communication strategies to offspring survival are lacking. We examined the communicative patterns of mothers and offspring in the feral horse (Equus caballus) to better understand 1) the nature of mother-offspring communication throughout the juvenile stage; 2) the function(s) of mother- vs. offspring-initiated communication and; 3) the importance of mare and foal communication to offspring survival. We found that 1) mares and foals differ in when and how they initiate communication; 2) the outcomes of mare- vs. foal-initiated communication bouts consistently differ; and 3) the communicative patterns between mares and their foals may be important to future offspring survival. We submit that these results can help us to better understand the long-debated question: do the behaviors of young mammals confer delayed or immediate benefits to offspring? You'll have to come to the talk to find out…

P3-181 NUNEZ, SA*; SANGER, TJ; Loyola University Chicago; *snunez3@luc.edu*

The Effects of Hypoxia and Heat on Early and Late Development of Lizard Embryos

Thermal stress triggered by climate change may negatively affect ecology, reproduction, and life history of many species. Oviparous species may be severely impacted by climate change as their eggs will be laid and incubated at increasingly higher temperatures. The lack of oxygen, or hypoxia, and its role during thermal stress in embryogenesis has been widely debated. In birds and mammals, hypoxia is known to induce craniofacial and neural malformations during development. In lizards, oxygen limitation is thought to set the thermal range of embryonic development. Thermal stress in the early embryonic development of *Anolis* lizards leads to malformations and even death. In our study, hypoxia did not induce malformations in anole embryos. We compared survival rates and developmental staging of embryos incubated under hypoxic and normoxic embryos in early (day 0-14) and late (day 10-20) development. We discovered survivorship of hypoxic embryos was higher in the early than in the late development, with delayed growth and reduced body sizes in late-stage hypoxic embryos, demonstrating that early reptilian development may be more robust to hypoxia. Additionally, we studied whether cellular-level hypoxia is limiting the thermal response of the developing anole embryo of standard and elevated incubation temperatures in both early and late development. Our preliminary results suggest there are stage-specific effects of hypoxia and thermal stress, as they interact to impede the more sensitive late-stage development of anole embryos. Discovering the effects of hypoxia during thermal stress in early and late reptilian development will help us better understand the potential impacts of climate change on reptiles.

67-2 NYAKATURA, J.A.; Humboldt University, Berlin; *john.nyakatura@hu-berlin.de*

Analyzing the Locomotion of a Stem Amniote: Orobates pabsti

Understanding the locomotion of extinct vertebrates offers insight into their paleobiology and helps to conceptualize major transitions in vertebrate evolution. Reconstruction of a fossil's locomotor behavior, however, remains problematic, because of the limited information preserved and lack of one-to-one correspondence between form and function. No quantitative and reproducible approaches to reconstruct locomotor characteristics of stem amniote fossils are available, and generally methods suffer from overreliance on anatomical features, ambiguous locomotor information preserved in ichnofossils, or unspecific modelling of locomotor dynamics. We attempted to reconstruct gaits of *Orobates pabsti*. We present an integrative methodological framework that uses constraints from quantified metrics for energetic efficiency, balance, dynamic similarity and precision of matching fossil tracks. Our framework uses in vivo assessment of locomotor mechanics in four extant species to guide an anatomically informed kinematic simulation as well as dynamic simulations and biorobotics to filter the parameter space for plausible gaits. Our approach might be useful for similar research into the locomotion of key taxa to gain insight into evolutionary transitions. Importantly, our quantitative and dynamic reconstruction can be extended and revised according to future methodological advances.

P3-121 NZIMA, MZ*; KOLAPE, J; SHIPLEY, M; WATSON, CM; Midwestern State University; *mnzima360@gmail.com*

Chitinase activity during digestion of insect prey by the Ground Skink, Scincella lateralis

Predators that consume arthropods must break down the chitinous exoskeleton in order to effectively and efficiently digest their prey. This is particularly problematic for small insectivores that eat smaller prey who, by virtue of a larger surface to volume ratio, contain more chitin per unit volume than larger arthropods. The enzyme responsible for digestion of the chitin polymer is chitinase. Chitinase has long been considered a product of the insectivore's gut biome and not secreted by their own cells. Here, we use the ground skink, *Scincella lateralis*, to test for chitinase production throughout the digestion of beetle larvae (*Tenebrio molitor*). We find that chitinase production in both the stomach and intestine initially rise upon consumption, level off, then increases as the materials pass through each section. We also show evidence that the lizard rather than its gut biome produce the chitinase.

63-4 O'BRIEN, HD; OSU Center for Health Sciences; *haley.obrien@okstate.edu*
Parallel Evolution of Selective Brain Cooling in Artiodactyls
Selective brain cooling (SBC) is a mechanism by which artiodactyl mammals stabilize brain temperatures below rising body temperatures. By lowering hypothalamic temperature, SBC significantly reduces evaporative water loss (≤6 liters/day). SBC is thus a hypothesized adaptation for surviving warming and drying climates. This physiology is driven by counter-current heat exchange across a high surface area cerebral arterial meshwork called the carotid rete (CR). The CR functionally and anatomically replaces the internal carotid artery (ICA), delivering cooled blood to the brain. Absence of the ICA relegates different branches of the embryonic aortic arches to supply the CR and brain. Compensatory branches vary on a suborder-specific basis: Suinamorpha by aortic arches 2 and 3; Camelidamorpha by arch 3; and Ruminantiamorpha by arch 1. These divergent cranial arterial development patterns suggest that there may be different mechanisms for achieving SBC within artiodactyls, and that the CR may be homoplastic. Here, I use basicranial osteological correlates to survey aortic arch contributions to the CR across Artiodactyla. I then map these results onto a phylogeny of artiodactyls and use ancestral character estimation to infer the evolutionary history of CR development. This analysis infers independent evolution of the CR and SBC for each suborder. Features that arise via such homoplastic parallelism are typically considered to be the result of developmental constraints, rather than the result of adaptive responses to selective pressures. This is a surprising conclusion given the hypothesis that the CR and SBC are adaptations to hot, dry environments. Future studies should incorporate specimens from the fossil record to better parse between parallel and convergent evolutionary mechanisms that may underlie cerebral arterial patterns in artiodactyls.

S11-2 O'BRIEN, Devin; Colby College; *dmobrien@colby.edu*
Canine Evolution in a Saber-toothed Cat (Smilodon fatalis): Static Scaling and Evidence of Natural Selection
The canines of saber-toothed cats are a classic example of an extreme morphology, yet we know surprisingly little about how they evolved. Natural observation of these animals is impossible, and few extant species have comparable morphology. As a result, we must infer the strength and mode of selection that acted on saber-tooth canines from the fossil record, a practice that, until recently, was associated with a high degree of uncertainty. Here, I review recently established methods for inferring the strength and mode of selection from measures of static scaling. I then expand and improve upon these methods and apply them to a fossil population of saber-toothed cats (*Smilodon fatalis*) collected from the La Brea Tar Pits (Los Angeles, USA; Merriam, 1912). I show how static scaling relationships can be useful, reliable tools for inferring patterns of selection, especially in fossil organisms, and provide evidence that extreme canine morphology in saber-toothed cats is the product of strong natural selection.

P2-165 O'CONNOR, E*; CORNELIUS, E; VéZINA, F; JIMENEZ, A.G.; JIMENEZ, ANA; Colgate University, Université du Quebéc à Rimouski; *ajimenez@colgate.edu*
Environmental Mismatch During Cold Shock in Black-capped Chickadees and Its Effects on Muscle Ultrastructure.
Previous work on maximal thermogenic capacity (Msum) in wild black-capped chickadees has revealed that phenotypic adjustments seem slow and begin to take place in early fall, well before the peak of winter cold. However, when mean minimal Ta reaches -10°C, the birds' phenotype provide enough reserve capacity in cold endurance to buffer days with Ta of -20°C or below. Birds and mammals have muscle fiber diameters that typically range from 10-100 µm. Minimal fiber diameters are limited by diffusion constraints for O2 and ATP while maximal fiber diameters seem to be dictated by the cost of the Na+-K+-ATPase on the sarcolemmal membrane. Although muscles mass is flexible in size, often being larger in winter; whether cold acclimated birds change muscle ultrastructure in response to sudden environmental challenges is unknown. Here, we investigated whether cold (-5°C) acclimated chickadees challenged with an experimental decline in temperature alter their muscle ultrastructure at the cell level in the first 3 h after a 15°C temperature drop. We compared muscle ultrastructure in birds that experienced the temperature decline (treatment ; -5°C to -20°C) to that of individuals remaining at -5°C (control). We found that treatment birds had a significantly higher total capillary density (0.005 ± 0.0003 capillaries/um2) compared with control birds (0.004 ± 0.0002 capillaries/um2). Treatment birds also had more nuclei per fiber (113.84 ± 3.72 nuclei/fiber) compared to controls (95.23 ± 2.97 nuclei/fiber) and had significantly smaller myonuclear domain (7432.33 ± 421.19 µm3) compared with control birds (8853.65 ± 369.01 µm3). Our data, therefore, suggest that cold acclimated birds can adjust their muscle cell phenotype within hours during cold spells.

54-7 O'CONNOR, M.P.*; NEEMAN, N.; SPOTILA, J.R.; Drexel University; *oconnomp@drexel.edu*
Physiological influences on sea turtle remigration intervals
Interannual, sometime cyclic, variation in numbers of sea turtles nesting on beaches complicates estimates of both population sizes and trends and can affect population dynamics. We update and extend an earlier, probabilistic, physiologically-based model of the effects of variation in ocean temperature and resources on intervals between sea turtle nesting migrations. As with earlier models, simulations suggest that variation in temperature (and induced variation in resource acquisition) might induce variation in sea turtle remigration but is unlikely to create sustained cycles in migration. Additional results from the refined model include: 1) predicted immediate responses to pulses of increased/decreased resources depends both on the magnitude of the resource pulse and on recent resource levels, 2) time to return to a baseline depends primarily on historical and ongoing resource levels, 3) lower resource levels result in prolonged ‘ringing' of the migration response around a baseline and increased ability to support short term cycling of remigration. Hence lower resource levels would be expected to result in short term cyclicity of migration rates. Attempts to match predicted variation in migration rates due to historical temperature variation at several leatherback nesting beaches were complicated by substantial local and regional variation in responses of resources (estimated by net primary productivity) to variation in sea surface temperature.

53-5 O'DONNELL, M.K.*; DEBAN, S.M.; University of South Florida; *mkodonnell@mail.usf.edu*

The effect of substrate roughness and porosity on salamander cling performance

Plethodontid salamanders have good clinging and climbing performance in their natural environments, enabling scansorial species to access food, shelter, or beneficial microclimatic conditions through adhesive and gripping attachments to inclined, elevated, and inverted surfaces. Our testing has shown that plethodontid species with different body sizes and morphologies have significantly different cling performance on smooth acrylic surfaces. While surface area of adhesion has been shown to affect performance, bolitoglossine salamanders with webbed feet have also been hypothesized to use foot suction to enhance attachment. We tested how a porous surface that eliminates suction affects cling performance in 14 species of salamanders. We found that porous surfaces had no effect on maximum cling performance, regardless of foot morphology, refuting the suction hypothesis. We also tested the effect of surface roughness on cling performance. Surface roughness had a significant effect on maximum cling angle, and the effect varied significantly among species depending on foot morphology and attachment mechanism. Surfaces of intermediate roughness (grit size 100 um to 350 um) resulted in the poorest attachment performance for all species. Webbed species performed best on smooth surfaces, while species with long, dexterous toes showed significant improvement on the roughest surfaces (grit size 1000 um to 4000 um), switching from adhesive attachment on a smooth surface to a gripping attachment mechanism on rough surfaces. Studies of climbing mechanisms and performance and their relationship to surface properties may cast light onto how these animals have radiated into the largest family of salamanders in the world that occupy diverse habitats across an enormous geographical range.

P3-173 OAKEY, SJ*; SCHOENLE, LA; DOWNS, CJ; MARTIN, LB; University of South Florida, Hamilton College; *soakey@mail.usf.edu*

Brains, Sickness, and Longevity: Does a Relationship Between Brain Size and Immunity Underlie Variation in Survival Rates?

Bigger brains are associated with higher survival rates among species, but is greater intelligence the cause? The cognitive buffer hypothesis suggests that animals with larger brains have higher survival rates because greater cognitive abilities can help animals successfully respond to challenges in their environments. However, larger relative brain sizes are associated with numerous other traits, including lower metabolic rates (per gram), and in some cases, stronger immune defenses. The higher survival rates in large-brained species might be at least partially explained by stronger parasite defenses. Alternatively, the high energy requirements of the brain, which consumes more calories per unit mass than other organs in the body, might force a trade-off between maintaining the brain and immune function. As a result, animals with larger brains might exhibit weaker immune defenses. We investigated the relationship between immunity and relative brain size of over 100 species of terrestrial mammals. We also examined how both immunity and brain size relate to longevity. We obtained mammalian brain size data from a database of mammalian species. We assessed constitutive immune function by quantifying the ability of serum to kill four different microbes: *Escherichia coli, Salmonella enterica, Candida albicans*, and *Micrococcus luteus*. Not only will we look at how brains and immunity relate across a wide list of varying animals, we will discuss how constitutive immune varies with brain size, longevity, and body mass and examine trends between orders such as primate, carnivora, artiodactyla, and rodentia. A comparison between orders, for example carnivora and primate, may reveal how diet and lifestyle impacts immunity and brain size of species.

S9-2 OAKLEY, Todd H.*; PICCIANI, Natasha; SWAFFORD, Andrew J.; OAKLEY, Todd; University of California, Santa Barbara; *oakley@lifesci.ucsb.edu*

Multi-modal sensory systems and the journey to the origin of animal phototransduction

Learning how complex traits like eyes and other sensory systems originate is fundamental for understanding evolution. One way to study trait origins is to trace the evolutionary history of their component parts. In this way, we can learn when the parts of complex traits came together during evolution and perhaps understand why and how they stayed together. To inform how eyes originated, our lab is reconstructing the evolutionary history of phototransduction, the cascade of protein interactions leading to sensing photons. We find that opsin - the keystone protein of phototransduction - has a dynamic and ancient evolutionary history. Already in the first Bilaterian animals, there were at least nine different opsins, even though no modern group retains all of these. Despite similar genes and light sensitivity in some fungi, we do not find this opsin family outside of animals, indicating opsins arose from other GPCR genes within animals. We studied phototransduction in Cnidaria and discovered it to be used in sensory cells adjacent to cnidocytes (‘stinging cells'). To previously known functions of chemo- and mechanosensation, we added photo-sensation to the repertoire of factors that influence cnidocyte firing. We find modulation of cnidocyte firing by light in a diversity of cnidaria, indicating the function could be ancestral and predate many separate eye origins in Cnidaria. While searching for animal-type opsins in fungi, we discovered certain zoospores to have multi-modal sensory systems, although using different molecular mechanisms compared to Cnidaria. In general, we learn that the history of the senses is ancient and intertwined, often using similar or homologous mechanisms, and often co-opting existing genes for new uses.

S1-2 OGBURN, R.M.*; EDWARDS, E.J.; DONOGHUE, M.J.; Southern Utah University, Yale University; *mattogburn@suu.edu*

Linking Plant Scaling Relationships and Ecology

Corner's rules describe a set of plant morphological scaling relationships between leaves, twigs, and branching density. These scaling relationships are likely dictated by physiological and biomechanical constraints, and are likely to correlate broadly with a species' ecological strategy. In the angiosperm species that have been studied to date, a broad but consistent relationship between leaves and twigs has been remarkably well supported. However, most of the previously examined species are ecologically similar broad-leaved angiosperm trees of temperate North American and east Asian forests. We followed a two-pronged approach - within a lineage and across ecological communities - to investigate ecological correlates of variation in twig-leaf scaling. Within the lineage Viburnum, which demonstrates significant evolutionary lability in leaf size and shape, we found consistent twig-leaf scaling relationships, with only several showing extreme twig-leaf ratios (leaves that are either "too big" or "too small" for a given twig size). This indicates that during the evolution of leaf morphological diversity in this clade, Corner's rules have been broadly maintained, suggesting that leaves and stems do not evolve independently. We also tested whether the unique ecological pressures of arid environments would result in different leaf-twig scaling in dryland angiosperms from across many lineages when compared with temperate broadleaved species. Our results confirm that arid-adapted plants also show strong leaf-twig scaling, but the relationship is different: for a given twig diameter the leaves are proportionally smaller compared to broad-leaved plants in non-desert areas. These results within Viburnum and across ecological communities demonstrate divergent but ecologically relevant patterns of twig-leaf scaling in angiosperms, indicating that architectural "rules" are made to be broken.

S9-1 OKAMURA, Beth; Natural History Museum, London; *b.okamura@nhm.ac.uk*

Introduction

Extant early diverging metazoans (Cnidaria, Ctenophora and Porifera) have survived in a changing and increasingly complex world. The interactions of these animals with their abiotic and biotic environments have shaped both their ancient and present-day patterns of development, phenotypes and, in turn, their environments. Many of these interactions are mediated by chemicals that may function in recognition (e.g. of predators, prey or suitable habitats) or are deployed as effectors. The diversity of such chemical mediators is now being revealed by whole genome and transcriptome sequencing platforms along with technical advances in proteomics, metabolomics and bioinformatics that provide insights on non-model systems. The aim of this symposium is to develop a post-genomic view on the forms, functions and origins of compounds that are biosynthesized in early diverging metazoans in response to environmental challenges and opportunities. Accordingly, symposium contributions will consider how these "simple" early-diverging metazoans exhibit a diversity of chemical responses to generate signaling, sensory, defensive and offensive capacities many of which are typically associated with "higher" animals. Our contributions address three general areas: the molecular basis of perception, chemicals deployed to deal with the biotic and abiotic environment, and the molecular cross-talk that characterizes intimate interactions amongst hosts, parasites and symbionts. Insights on the diversity of such chemical adaptations may afford new perspectives on the evolution of chemical mediators and promote a general understanding of functional biochemistry for an audience with fundamental interests in comparative and integrative organismal biology.

100-2 OKAMURA, B; Natural History Museum, London; *b.okamura@nhm.ac.uk*

A passion for colonies

Unlike you and I, many animals form physiologically-integrated colonies of asexually-iterated modules - to me a bizarre and fascinating evolutionary trajectory that has resulted in complex and aesthetically-inspiring forms. This has motivated questions such as what drove the evolution of such a distinct life history? And what are the consequences of iterating units or modules to achieve an increase in organismal size and the associated development of differing colony architectures? This led me to examine how variation in both ecological settings and colony morphologies impact resource acquisition - employing this as an approach for understanding the consequences and perhaps drivers of coloniality in the animals that we can study today. In this talk I will focus on how I have periodically tackled this issue from its infancy inception as a PhD student to more recent times.

S3-1 OLBERDING, JP*; AZIZI, E; DEBAN, SM; ROSARIO, MV; Univ. of California, Irvine, Univ. of South Florida, West Chester Univ.; *olberdij@uci.edu*

Energy flow in elastic structures: not so unusual

The past two decades have seen significant advances in our understanding of energy flow in organismal movements, particularly in the role of elastic structures mediating energy flow to amplify or attenuate power, or to recover energy during cyclic movement. While initially studied in a handful of extraordinary systems, storage of energy in elastic structures is now recognized as broadly integral to organismal movement. The role of energy transfer between the organism and environment is also recognized as critical to understanding movement, including impact mechanics during striking, energy exchange with substrates, and even movement actuated by external energy sources. This symposium will explore the diverse ways in which energy flows between structures in a vast array of organismal movements. Here we present evidence that the use of elastic structures may be more widespread in vertebrate musculoskeletal systems than previously believed and that such mechanisms may play a critical role in movements other than "extreme performance". Hybrid *in vitro* computer models of frog hind limbs reveal that storage and release of elastic energy does not require radically modified morphology, but simply the presence of sufficient elastic structures. Additionally, examination of tongue projection in plethodontid salamanders reveals that the evolution of elastic energy storage may require only relatively simple morphological changes to existing structures, particularly the elaboration of elastic structures. Energy moving through elastic structures may be expected in any system where such a structure is present, even if power is not amplified or attenuated beyond muscle capabilities. Mediation of energy flow by elastic structures may be critical for timing of movements and may optimize work done by muscle.

10-5 OLSEN, AM*; HERNÁNDEZ, LP; CAMP, AL; BRAINERD, EL; Brown University, George Washington University, University of Liverpool; *aarolsen@gmail.com*

Channel catfish use higher coordination to capture prey than to swallow

When animals move they must coordinate motion among multiple parts of the musculoskeletal system. While different behaviors exhibit different levels of coordination it remains unclear what general principles determine what level of coordination is ideal for a particular behavior. One hypothesis is that velocity determines coordination levels as a result of differences in active versus passsive motor control. An alternative hypothesis is that coordination is determined by the extent to which the motor system engages in one task (monotasking) versus multiple tasks (multitasking). To test these hypotheses we measured motor coordination within the highly kinetic skulls of channel catfish during feeding. We used X-ray reconstruction of moving morphology (XROMM) and joint model fitting to reduce the 3D movements of 7 skeletal elements into 8 principal motions and cross-correlation to measure changes in motor integration, which we argue represent changes in coordination. We found that motion was significantly more coordinated (by 25%) during prey capture than during transport, supporting the hypothesis that motor mono- versus multitasking determines coordination levels. We found no significant difference in coordination between motions grouped by speed or intraoral pressure. We propose that capture is more coordinated to create a single fluid flow into the mouth (monotasking) while transport is less coordinated so that cranial elements can more independently generate multiple flows to reposition prey (multitasking). Our results demonstrate the benefits of both high and low coordination for natural animal behaviors and the potential of motion data to reveal how the neural system structures animal movement. Funded by NSF grants 1612230, 1655756, and 1661129.

S1-5 OLSON, Mark E. ; Univ. Nacional Autónoma de México;
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Plant Evolutionary Ecology In The Age Of The Extended Evolutionary Synthesis
Plant ecology is increasingly turning to evolutionary questions, just as evolutionary biology pushes out of the strictures of the Modern Synthesis into what some regard as an "Extended" Synthesis. As plant ecology becomes increasingly evolutionary, it is essential to examine how aspects of the Extended Synthesis might impinge on plant ecological theory and practice. I examine the potential of niche construction theory, developmental systems theory, and genes-as-followers adaptive evolution in providing novel perspectives for plant evolutionary ecology. I also examine the implications of overcoming dichotomies such as genetic vs plastic, biotic vs abiotic, genotype vs phenotype, and constraint vs adaptation, and how shedding these traditional false dichotomies provides fertile opportunities for plant evolutionary ecologists. Along the same lines, outgrowing vague concepts such as "stress" and "constraint" and replacing them with more precise terminology in all cases provides vastly increased causal clarity. As a result, the synthetic path that plant ecologists are blazing, becoming more evolutionary every year, bodes extremely well for the field, with vast potential for expansion into important scientific territory.

2-3 ONG, J*; BONIER, F; Queen's University at Kingston;
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Coping with thermal challenges: reaction norms of life history traits in a burying beetle with biparental care
Most organisms encounter some degree of environmental variation throughout their lifetime. To succeed and thrive in different environments, individuals can express plastic phenotypes, including plastic life history traits, to ensure some level of fitness across conditions. Previous work has described how several traits relevant to fitness respond to different temperatures, but much of this work has focused on only one or a few traits, and overlooked the interactions between traits. Few have considered the effects of temperature on parental care - a highly labile trait that can have important effects on fitness. Here, we take an integrative approach to study how organisms cope with temperature variation in their environment. We characterized thermal reaction norms of several life history traits and parental behaviours in the burying beetle *Nicrophorus orbicollis*. Both male and female *N. orbicollis* exhibit complex parental care behaviours, including directly provisioning food to their larvae. We find that life history traits show varying levels of plasticity across temperatures, and some traits exhibited family-level variation in reaction norms, which might reflect underlying heritable variation in plasticity. Temperature affected per capita parental care, offspring size, and brood size. We also found that eclosion success across temperatures varied between families, and that there may be constraints on parental care that prevent *N. orbicollis* from increasing overall levels of parental care sufficiently to buffer against challenging temperatures. Taken together, our results suggest that life history responses to temperature reflect the incorporation of several reaction norms, which vary among families and have important fitness consequences.

P3-95 ONTHANK, KL*; CULLER, ME; Walla Walla University;
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An Inexpensive pH-stat System Based on Open Hardware for Ocean Acidification Research
Pseudoreplication and similar experimental design errors continue to be prevalent in ocean acidification (OA) research. One of the major impediments to creating properly replicated trials is the cost of purchasing enough control systems to independently regulate CO_2 concentration in separate holding tanks. To bring down the cost of such replication we developed and tested a pH-stat system constructed largely with open hardware. This pH-stat controller was built around an Arduino Mega 2560 microcontroller board, using an Atlas Scientific EZO pH circuit to interface with the pH probe, an Adafruit MAX31865 to interface with a PT100 temperature sensor, and controlling pH by actuating a solenoid valve to deliver pure CO_2 gas to a bubble stone immersed in the holding tank water. These systems were tested over a 3-week period with a single octopus occupying each controlled holding tank. Tank pH was periodically verified using the m-cresol purple photometric method. We found the control system performs comparably to similar units commercially available for a fraction of the price, possibly making appropriately replicated OA treatments available to many more institutions.

20-5 ONTHANK, KL; Walla Walla University;
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Shouting into the Abyss or Preaching to the Choir? My Experience 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 creates fertile soil for beliefs among the public such as a massive conspiracy among scientists on issues such as climate change. To help address the widespread misunderstanding of the process of science, I began a video blog (vlog) on YouTube named "Octopodium". During the following three years I have posted thrice weekly videos following the progress of research in my lab during my summer field season. The goal of Octopodium is to communicate to an audience of non-scientists how scientific research works on a day-to-day basis. Over the course of these three 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 20,000 times. While I have found this mode of scientific communication to offer a rich and in-depth view of the work of a research scientist, it can also be incredibly 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.

P3-49 ORNDORFF, C*; LIBBY, T; DANIEL, TL; University of Washington; *tlibby@berkeley.edu*

A haptic virtual reality device to probe motor integration in tethered moths

Flying insects are known to control orientation via torques arising from at least three distinct affordances: by varying aerodynamic center of pressure, by changing body posture to alter center of mass location, and by swinging body segments or limbs to exert inertial torques. Each affordance is subject to distinct constraints, saturations, and sensitivities, as potential coupling to the control of center of mass forces (e.g. vertical support). We hypothesize that these sources of control are integrated in parallel to increase robustness and agility, are weighted according to behavioral context, and are tuned to body morphological parameters. To investigate affordance integration in flight, we built an actuated armature to apply rapid pitch movements to a tethered flying moth, *Manduca sexta*, while measuring the torque exerted by the moth's flight forces and body movement. Closing the loop between measured torque and applied movement enables control of the forces experienced by the moth while allowing pitch movement (e.g. a haptic environment); a video screen enables visual experience to either match mechanosensory experience or be rotated with the moth to provide sensory conflict (e.g. a virtual reality environment). We used our device to apply short perturbations and examined the magnitude of torques arising from each affordance. Body kinematics were recorded with a high-speed camera and combined with morphometric data to estimate inertial torques and center of mass motion associated with abdominal flexion. These estimates were combined with measurements of total pitch axis torque to estimate the torque generated by the three affordances during the perturbations. Moths appear to employ parallel strategies to generate torques counter to the perturbations, consistent with a stabilizing response.

110-7 ORR, TJ*; YAMADA, KY; SHAPRIO, M; DEARING, MD; University of Utah, Auburn University; *teri.orr@utah.edu*

Diet Switching in mammalian herbivores: differential tolerances of two woodrat species and their hybrids to toxic diets

Herbivores confront the possibility of being poisoned by their food, which contains plant secondary compounds (PSCs). The mechanisms used by mammalian herbivores to metabolize PSCs are poorly understood, particularly with respect to specialization on toxic diets. We are investigating the evolution of dietary specialization in herbivores by studying dramatic diet changes in woodrats (*Neotoma* spp.). Starting approximately 18,000 years ago, populations of two woodrat species switched from feeding on juniper and cactus to diets rich in creosote bush (*Larrea tridentata*), a shrub containing high levels of toxic compounds. These different food sources have radically disparate PSC profiles and thus require different hepatic enzymes for biotransformation. We assayed the ability to tolerate creosote toxins in 12 populations of two species of woodrats (*N. lepida, N. bryanti,* and their hybrids). Some of these populations are obligate creosote feeders, while others feed on the ancestral diet. In laboratory feeding trails, we determined the maximum tolerable dose (MTD) of creosote resin. MTD varied between species, with *N. lepida* having the highest MTD, ~1.5 times that of *N. bryanti*. Hybrids were intermediate. This pattern was evident across collection sites, and within a site where both species occurred and creosote dominated the landscape. Surprisingly, access to creosote bush did not explain tolerance variation: we found no differences in MTD between populations within a species with or without access to creosote bush. Instead, MTD was negatively correlated with increasing distance from the proposed origin of creosote bush invasion in southwestern North America (R2=0.69, p=0.002). We are currently conducting genomic and transcriptomic analyses to identify the genomic basis for dietary specialization on creosote bush.

P3-22 ORTEGA, R*; MCCARTY-GLENN, M; MEHTA, RS; WARD, AB; Adelphi University, Univ. of California, Santa Cruz, 1978; *award@adelphi.edu*

Role of substrate during terrestrial locomotion in Asian Swamp Eels (Monopterus albus)

Highly elongate fish, from a number of distinct lineages, have traversed the water-land boundary. This movement between extreme environments is often motivated by habitat quality or lack of prey. Asian Swamp Eels (*Monopterus albus*) are found in rice fields and have been observed moving on mud flats to locate new bodies of water often around the breeding season. Laboratory study of *Monopterus* indicated that emergence from the water is often linked to starvation or increased population density. Previous study of pectoral fin-based terrestrial locomotion in fishes has shown the importance of the posterior end of the body for forward propulsion. Elongate fish tend to have highly reduced or absent paired fins, especially in the pectoral region, and thus must rely wholly on movement of the axial skeleton to move forward. Our work has shown that, similar to limbless tetrapods, elongate fishes use push-points in their environment during locomotion. In this study, we tested the role of substrate on body mechanics during undulatory locomotion; specifically we examined how compliance of a substrate affects forward movement. Individuals of *M. albus* were filmed moving across three different substrates: hard-packed sand, small loose pebbles, and small fixed pebbles. Fixed pebbles were secured onto the substrate and to each other with glue. We found that substrate did affect movements such as distance ratio and wave amplitude. This research, which is part of a larger comparative study on terrestrial movement in highly elongate fishes, will identify how different substrates may facilitate or constrain movement on those fishes that mostly rely on lateral undulation of the axial skeleton.

P2-198 ORTIZ, TE*; CHANDLER, C; Department of Biological Sciences, SUNY Oswego; *tortiz2@oswego.edu*

Testing for Wolbachia Infection in Aquatic Isopods

Wolbachia is a very common endosymbiotic bacterium that can affect its hosts in various complicated ways. It can affect some nematodes and numerous arthropods, including terrestrial isopods." The focus of our research was the potential effects Wolbachia can have on not only terrestrial isopods, but also aquatic species of isopods as well. Using PCR, specimens were obtained from the Rice Creek Field Station in Oswego, New York, which were then analyzed to determine species and sex. The species, Caecidotea racovitzai, was identified and then several of the collected specimens were tested for Wolbachia. Our initial results showed little to no Wolbachia infection, but may be skewed because of the limited sample size being tested at the time. We are currently testing additional samples, as well as a marine isopod species, Idotea baltica, that we plan on working further with in the lab to test prevalence of Wolbachia in freshwater and marine isopods.

6-6 ORTON, RO*; SCHIELD, DR; ROW, KW; NIKOLAKIS, ZL; PERRY , BW; DEMUTH, JP; MACKESSY, SP; MEIK, JM; CASTOE, TA; Univ. of Texas, Arlington, Univ. of Northern Colorado, Tarleton State University ; *richard.orton@uta.edu*

Variation in genetic diversity and differentiation across chromosomes in rattlesnakes reveal links between genome structure and speciation

Different genomic regions vary in mode of inheritance, rates of recombination, and effective population size, which may result in contrasting patterns of genetic diversity and evolutionary history. For species with genetic sex determination, distinct patterns of inheritance among the autosomes, sex chromosomes, and mitochondria may provide particular insight into patterns of demography and sex-biased gene flow. Here, we sampled genetic variation from nuclear and mitochondrial RADseq loci from three pairs of rattlesnake lineages (genus *Crotalus*, and interpreted these data using a chromosome-level reference genome for the Prairie Rattlesnake (*Crotalus viridis*) to compare and contrast patterns of variation, population genetic structure, and differentiation among genomic regions. Within populations, we find that sex chromosomes and mitochondria exhibit patterns of genetic diversity different from autosomes, including nucleotide diversity (π) and -based effective population size estimates. We also find that between-population comparisons of differentiation (FST) and estimates of demographic history provide consistent evidence for allopatric divergence followed by secondary contact with gene flow across genomic regions. Our results illustrate the power of interpreting population genetic variation in the context of chromosomal genome assemblies for understanding the early stages of speciation, and demonstrate consistent and sex-biased signals of gene flow in secondary contact in rattlesnakes.

P1-209 OSBORN, AL*; AMBROSE, A; CHAMBERS, C; CORDERO-MARTíNEZ, C; SHRILEY, K; SILVA, S; MARKLAND, S; TWOMBLY, J; GONZALEZ, V; TSCHEULIN, T; PETANIDOU, T; BARTHELL, JF; College of NJ, Savannah St. U, U Kansas, U Puerto Rico, CO College, OK St. U, Cornell U, U Kansas, U Aegean, U Central OK; *osborna3@tcnj.edu*

Effect of Pan Trap Size on Catch: Determining Protocol for Pollinator Monitoring

Bees are key pollinators, but many populations and species are declining. Monitoring bee health and pollination are priorities to safeguard pollinators and secure their services. Pan trapping is a popular method to survey bees, but efficacy assessments of this method are limited. Little is known about effect of bycatch, which increases processing time and costs, and may affect beneficial arthropods. We tested the hypothesis that large traps increase abundance, diversity, species richness, and body size of bees, and bycatch abundance. Field studies were conducted in 3 habitats in Lesvos, Greece: a semi-natural phrygana scrub, an olive grove, and a salt flat. Arthropods were collected from transects of 4 sizes of traps (1.0, 3.25, 5.0, 12.0 Oz). 13,155 arthropods were collected, of which bees accounted for 37.2% and 109 species. Pairwise comparisons indicated that 5.0 and 12.0 Oz traps captured a larger bycatch. 3.25 Oz traps yielded the same abundance, species, diversity, and body size of bees; there was also no correlation between trap size and these variables. Larger traps (5.0, 12.0 Oz) caught significantly more bycatch. Results suggest that 3.25 Oz traps are an optimal size for pollinator surveys; catching the same abundance, species, diversity, and sizes of target arthropods, while minimizing bycatch. This trap size is less likely to tip over or evaporate as quickly as 1.0 Oz traps, and uses fewer resources than larger traps, making it more sustainable. Our findings suggest a practical and reliable means for conservationists to monitor pollinator populations and assess their ecological role.

50-5 OSWALD, JA*; ALLEN, JM; LEFEBVRE, MJ; STEADMAN, D; GURALNICK, R; University of Florida; University of Nevada, Reno, University of Florida , University of Florida ; *oswaldj3@gmail.com*

Using ancient DNA to elucidate extinct taxon relationships and to understand the historical biogeography of the Caribbean

At the end of the Pleistocene (~13,000 years ago) a mass extinction began that has resulted in a significant loss of Earth's biodiversity. Remarkably, many Pleistocene species survived on islands until they were colonized by humans. In the Caribbean, large animals (e.g. giant tortoises and ground sloths) along with many birds and small mammals survived until human colonization during the Holocene, between 5,000 - 1,000 years ago. Here we focus on Bahamian hutia, *Geocapromys ingrahami*, the only native terrestrial mammal in the Bahamas. This large rodent is thought to have been managed as a food resource by Amerindians soon after they colonized the islands. Previous fossil and archaeological studies indicate Bahamian hutias were once widespread across the Bahamas and were able to inhabit a diversity of island settings. Today, extant hutia populations are vulnerable and are limited to three small cays. We extracted ancient DNA from fossils of extirpated populations that yielded nearly complete mitochondrial genomes from *G. ingrahami* from four banks of the Bahamas. We found that an extinct northern subspecies of *G. ingrahami* was genetically distinct from other populations highlighting the loss of biodiversity in Bahamas. We also use these data to place the Bahamian hutia in a wider phylogenetic context with other non-Bahamian hutia species. Our results augment the emerging understanding of human-caused biodiversity declines on Caribbean Islands.

53-7 OTHAYOTH, R*; THOMS, G; LI, C; Johns Hopkins University; *ratan@jhu.edu*

Animals and robots vibrate to explore locomotion energy landscapes to make locomotor transitions

Animals often move through complex terrain by transitioning between locomotor modes. For example, to traverse grass-like beams, the discoid cockroach can push across, climb over, or roll its body to maneuver through gaps. Interestingly, the animal frequently transitions from more difficult (slower) locomotor modes (e.g. climbing, pushing) to the easiest (fastest) rolling mode. In addition, its body vibrated vigorously during traversal due to oscillatory leg pushing against the terrain. Inspired by these observations, we hypothesized that kinetic energy fluctuation from the seemingly wasteful body vibration helps legged animals explore a locomotion energy landscape and overcome potential barriers to find more favorable locomotor modes. We tested this hypothesis by studying how cockroaches and a robophysical model transitions from climbing to rolling when traversing grass-like beams and modeling their locomotor-terrain interaction using a locomotion energy landscape. We found that both systems overcame a lower potential barrier to traverse by rolling than by climbing, i.e., the rolling mode was terradynamically more favorable. In addition, as kinetic energy fluctuation decreased relative to mode-separating potential energy barriers, the animal was more likely and needed a longer time to transition from climbing to rolling. Kinetic energy fluctuation helps animals and robots overcome mode-separating potential energy barriers to explore the landscape to escape from less favorable modes and find more favorable modes. Our study demonstrates the usefulness of locomotion energy landscape for understanding how macroscopic, self-propelled, legged locomotors interact with terrain to probabilistically transition between locomotor modes, and is a step in establishing terradynamics of locomotion in complex 3-D terrain.

91-2 OUFIERO, CE*; ROCK, A; EISINGER, MB; LONGO, SJ; WAINWRIGHT, D; Towson Univ., Duke Univ., Harvard Univ.; *coufiero@towson.edu*

The morphology and performance of a mutant knifefish with a dorsal fin

According to Dollo's Law the evolutionary loss of a complex feature is irreversible, such that organisms can never completely regain or return to an ancestral state. Among fishes, loss and subdivision of fins is far more common than regaining lost fins, supporting Dollo's Law. For example, Gymnotiformes (knifefishes and electric eels) are an order of weakly-electric freshwater fish that produce thrust through undulation of an elongate anal fin (gymnotiform swimming), and all species completely lack a dorsal fin. This dorsal fin loss is seen in convergent Osteoglossiformes and Siluriformes, which also swim with anal fin undulation, suggesting the lack of a dorsal fin may play a role in the performance of gymnotiform swimmers. However, a mutant form of the gymnotiform black ghost knifefish (*Apteronotus albifrons*) that possesses an elongate dorsal fin has been found among captive bred populations. The presence of this mutant fish challenges Dollo's law by suggesting that fin loss is reversible and these mutants provide an opportunity to examine the effects of dorsal fin presence on gymnotiform swimming performance. The goals of this study were to 1) describe the morphology of this mutant knifefish and 2) compare aerobic and anaerobic swimming performance among mutant and wild type knifefish. We used µCT scans to describe dorsal fin morphology, respirometry to measure swimming energetics, and sprint speed for anaerobic performance. Preliminary results show that mutant knifefish have regained both fin rays and fin ray supports (pterygiophores), although the fin is not moved during swimming. We found no difference in swimming energetics and a reduction in sprint swimming performance. We discuss these results in the context of Dollo's law and major evolutionary transitions of fins among fish.

P1-4 OUFIERO, CE; Towson Univ; *coufiero@towson.edu*

The Organismal Form and Function lab-course: a new C.U.R.E. for engaging students in authentic research experiences in organismal biology.

There is an increasing realization that traditional "cookbook" labs may not expose students to the reality of conducting research. Instead of handing students a set of experiments with known conclusions, more educators are implementing authentic research experiences within the classroom, where the results are often unknown, even to the instructor. These courses, called Course-based Undergraduate Research Experiences, or C.U.R.E.s, allow students to learn laboratory techniques and scientific methods while enabling them to actively participate in research. C.U.R.E.s allow more students to participate in authentic research, and may lead to students presenting their research, becoming co-authors, or continuing in STEM related fields. However, most C.U.R.E. biology courses developed to date have focused on cellular and molecular topics, with few engaging students in other biological disciplines, such as organismal biology, functional biology, or ecology and evolution. As part of TU-REP, funded by Howard Hughes Medical Institute Inclusive Excellence Initiative, I developed a C.U.R.E. on organismal form and function, which was offered for the first time in the fall 2018. Using a scaffolding approach, students were instructed on form, function and performance relationships in the context of ecology, evolution and biomechanics. Students were also instructed on filming with high-speed cameras, digitizing, and analyzing their data to answer questions related to movement. Then, using guided inquiry and locally collected invertebrate species, students developed their own hypotheses on animal movement, collected, analyzed, and presented their data. I will present the course structure and application, student hypotheses and results, the benefits and challenges of teaching an organismal C.U.R.E., and results of student assessment.

140-7 OURA, T*; MAEDA , M; TANAKA, H; Tokyo Institute of Technology, Royal Veterinary College; *oura.t.ac@m.titech.ac.jp*

Three-dimensional wing motions of a diving penguin

Penguins are wing-propelled diving birds capable of maneuvers such as rapid turns or accelerations. Previous bio-logging studies and 2-D motion analysis studies have revealed the basic swimming characteristics such as average swimming speed, dive depth, or wingbeat frequency. However, the details of the 3-D wing and body kinematics are largely unknown, which will be the foundation of understanding the hydrodynamic force generation mechanism by the penguin wings (flippers). To obtain the 3-D kinematics, we recorded a swimming penguin in a large water tank at an aquarium using multiple waterproof video cameras at 60 frames per second. Based on the 3-D coordinates of the characteristic points on the penguins, the wing kinematics such as stroke angle, sweepback angle, feathering angle and angle of attack were calculated. The wing kinematics were used to obtain instantaneous fluid dynamic forces with the quasi-steady blade element method. The resultant forces were compared with the fluid dynamic forces obtained from the inverse dynamics by using the buoyancy force estimated from a simplified 3-D body model. We found that during turning maneuvers at slow speed, the angle of attack of the inner wing was notably large up to around 40° while the angle of attack of the outer wing was moderate, 25° or less. On the other hand, such drastic increase in angle of attack was not observed during slow forward swimmings. This suggests that the penguin could be able to largely change the fluid dynamic force of its wings for maneuvering due to wide operational range of angle of attack.

19-7 OUTOMURO, D*; ZUREK, D/B; TAYLOR, L/A; CRONIN, T/W; DHARMARAAJ, B; KUNTE, K; MOREHOUSE, N/I; University of Cincinnati, USA, University of Florida, USA, University of Maryland, Baltimore County, USA, National Centre for Biological Sciences, India; *outomuro.david@gmail.com*

The evolution of colour vision across jumping spiders

In many animals, vision plays a central role in navigation, foraging, and communication. The diversification of visual systems is thus important for exploitation of new visual niches. Jumping spiders are visually guided predators with principal eyes that provide high spatial acuity and colour vision. They also exhibit major differences in colour signalling across species, particularly in the use of long-wavelength colours. Given that most jumping spiders are thought to have UV-green dichromatic vision, we hypothesized that jumping spider groups that use of long-wavelength colours in communication may have evolved improved colour vision. Within a comparative framework, we investigated the number and peak sensitivities of photoreceptor types in the principal eyes of jumping spiders using microspectrophotometry. We identify one origin of trichromacy, in the Harmochirines and Pellenines. We also report two independent origins of tetrachromacy, one in the Euophryini and a second in the Aelurillina. Trichromacy is achieved using spectral tuning via an intraretinal long-pass filter, whereas both instances of tetrachromacy are achieved by the addition of photoreceptors with different spectral sensitivities. Jumping spiders thus represent a promising group for the study of repeated evolution of transitions of colour vision from dichromacy to tri- and tetrachromacy in terrestrial habitats. We discuss the potential role of predatory behaviour, sexual selection, light conditions and background complexity in the context of evolution of colour vision in this group of spiders.

97-7 OVERLI, O; Norwegian University of Life Sciences; *oyvind.overli@nmbu.no*

Pigments, parasites, and personalities: The role of cortisol and melanocortin receptor gene variants

In many vertebrate species, black eumelanin-based pigmentation patterns correlate with social dominance and high stress- and disease-resistance. In salmonid fishes (genus Salmo and Oncorhynchus) fish with high incidence of black melanin-based skin spots show proactive behavior, reduced post stress cortisol production, and harbour fewer ectoparasitic sea lice. Proximate molecular-genetic mechanisms for such trait associations has long remained enigmatic. Here I describe how a missense mutation in a classical pigmentation gene, melanocortin 1 receptor (MC1R), is strongly associated with distinct differences in steroidogenic melanocortin 2 receptor (MC2R) mRNA expression between genetically selected proactive (low-responsive, LR) and reactive (high responsive, HR) lines of rainbow trout (Oncorhynchus mykiss). Molecular dynamics simulation predict that melanocortin 2 receptor accessory protein (MRAP), needed for MC2R function, binds differently to the two MC1R variants. Experiments in vitro confirmed that trout MRAP interacts with the two MC1R variants and MC2R. Furthermore, mRNA for both MC1R variants and MC2R are present in head kidney cells. It would appear that genetically determined high vs low post-stress cortisol production is caused by MC2R activity being modulated in part by different binding affinities of MC1R gene variants for MRAP. We also show experimentally that exogenous cortisol increase the expression of agouti signaling protein (ASIP) mRNA in skin, which explains the association between HR-traits and reduced skin melanin patterning. Hence, skin melanisation, like immune function and a range of other traits, is modulated by the steroid hormone cortisol. The production of this hormone is in turn controlled by both environmental and genetic factors and, peculiarly, pigment genes can be found among the latter.

22-7 OWEN, DAS*; SHERIFF, MJ; LANGKILDE, T; The Pennsylvania State University; *dasowen27@gmail.com*

Effects of Maternal Stress on Lizard Heart Rate

Maternally-derived stress hormones, glucocorticoids, can induce phenotypic plasticity in many vertebrate taxa, and have consequences for resulting offspring. We tested the hypothesis that increased physiological stress of female eastern fence lizards (Sceloporus undulatus) while gravid will elevate heart rates of mothers and their offspring. Increased heart rates may facilitate energy allocation to deal with the environmental stressors, and can also speed development of offspring and decrease the amount of time in the vulnerable hatchling stage. Gravid females were dosed daily with topical corticosterone (CORT) until laying. Heart rate was measured five days after laying for mothers, and five days after hatching for hatchlings. We found that hatchlings of glucocorticoid-treated mothers had higher heart rates compared to hatchlings of control mothers. However, mothers from CORT-treated and control treatments had similar heart rates. Maternal stress appears to alter the physiology of offspring at five days of age, potentially speeding rates of development and resulting in earlier sexual maturity and larger body size, which could have important fitness benefits. Future work should investigate the adaptive significance of these maternal stress-effect to determine whether these offspring have increased fitness within high-stress environments.

P1-39 OZALP, MK*; MILLER, LA; Univ. of North Carolina, Chapel Hill; *mkoz@live.unc.edu*

The Effect of Immersed Structures on Zooplankton Swimming

Zooplanktons are vulnerable to strong flows and currents, such as in storms and flood conditions, given their small size. Reefs, macrophytes, and other structures can provide shelter against wash out as these structures alter the flow field around them significantly. It is not clear how the protective aspects of such immersed structures depend on their volume fraction, arrangement, and flexibility, and it is also not clear how organismal size and swimming speed scale against wash out. We use *Artemia*, or brine shrimps, as a model organism given their hardiness. We then use both experimental and numerical approaches to quantify the effect of macrophyte density and arrangement on flow. As a simplification, we use 3D-printed arrays with cylindrical protrusions as an initial model of the macrophytes. Using 2D Particle Image Velocimetry (PIV), the flow fields in the presence and absence of cylindrical arrays are measured. 3D immersed boundary simulations are then performed to resolve the flow fields around the cylindrical arrays, and the results are validated against PIV. Next, we inject nauplii within different arrays and for different background flow speeds. The distribution of *Artemia* over time is recorded with video. Finally, we compare the experimental results of Artemia distributions with an agent-based model that simulates the movement of plankton within the 3D flow fields produced by the immersed boundary simulations.

59-1 OZARKAR , S*; TAO, L; BHANDAWAT , V; Duke University ; *sso5@duke.edu*

Delineating the Relationship between Olfactory Receptor Neuron Activity and Behavior in Drosophila

Different odors activate distinct combinations of olfactory receptor neurons (ORNs).These combinations are decoded by downstream olfactory circuits to drive a variety of olfactory behaviors, including odor-modulation of locomotion.In this study, we will leverage the relative simplicity of the fly's olfactory system, and the availability of genetic tools to find the relationship between combinations of active ORNs, and the subsequent modulation of locomotion.This study focuses on the 7 ORN classes (out of total 60) that are activated by apple cider vinegar, an odor that is attractive to the fly [1].We employ an optogenetic approach to activate known subsets of these 7 ORN classes to understand the contribution of each ORN class to the modulation of locomotion in a circular arena, whose center is illuminated with light (odor-zone).As the fly enters the odor-zone, a known set of ORNs are activated.We measure how the distribution of flies in the arena is affected by activating different subsets of ORNs, and the motor mechanism underlying this change in distribution. Consistent with the previous study, we find that activating different ORN classes changes different aspects of a fly's locomotion.By comparing the effect of simultaneously activating multiple ORN classes with that of activating each ORN class individually, we are able to obtain insight into the rules by which ORN activities are integrated to affect behavior.We also make a generative model of behavior (see abstract Tao, Ozarkar, Bhandawat) which allows us to connect ORN activation pattern to the change in motor parameters to the change in the distribution of flies in the arena. References:
1.Jung, S.H., Hueston, C. & Bhandawat,V .Odor identity dependent programs underlie behavioral response to odors. *Elife* 4, doi: 10.7554/eLife.11092 (2015)

88-2 OZKAN-AYDIN, Y*; CULVER, J; TENNENBAUM, M.J.; GOLDMAN, D.I.; BHAMLA, S.; Georgia Tech; *yasemin.ozkanaydin@physics.gatech.edu*

Worm Blobs: Biophysical Principles of Survival in Worms via Aggregate Formation

Aggregate formation and clustering are common behaviors observed from bacteria to humans, and can facilitate the survival of the collective [Allee, 1978]. Worms have soft bodies with moist-skin and can thus individually suffer due to environmental stresses. Aquatic worms (*Lumbriculus variegatus* , ~3 cm long) naturally aggregate into multi-cm diameter ensembles of thousands of worms knotted together, forming an active viscoelastic 'blob'; these are presumed to confer benefits, but systematic studies are lacking. We are interested to subject the collectives to evaporative, thermal and mechanical stresses and measure mortality and damage of individuals. Here, we focus on thermal stresses, measuring the mortality rate as a function of cluster size (N=1, 5, 10, 20 worms, 10 replicates per condition) under controlled laboratory conditions. When single worms were placed on a dry plate at room temperature and humidity (24 °C, 48%), they died after 56 ±16 min while in a cluster with 20 worms, animals perished after 342 ±24 min; the time to death scaled approximately linearly with N. To gain insight into the dynamics of the blob and the worms, we performed time-lapse imaging, tracking the projected area (A) of the aggregate. Worms moved continuously throughout all clusters, presumably to keep their surfaces moist. For N<20, the aggregate monotonically reduced total surface area by shrinking into a circularly symmetric cluster. For N=20, the blob expanded for ~50 min until it achieved nearly double its projected area, after which it decreased in size. Final A before death increased with increasing N. We hypothesize that larger clusters first search for more favorable conditions before beginning a stereotyped shrinking to reduce surface area to volume to avoid evaporative losses.

P1-246 PABST, E; KOCOT, KM*; University of Alabama, Tuscaloosa; *kmkocot@ua.edu*

Are ultraconserved elements an informative phylogenetic marker for reconstructing deep molluscan phylogeny?

Although recent phylogenomic studies employing hundreds of nuclear protein-coding genes have greatly improved understanding of mollusc class-level phylogeny, placement of some lineages such as Scaphopoda and Monoplacophora remain unsettled. We investigated whether ultraconserved elements (UCEs), putative regulators of animal gene expression with very low rates of sequence evolution, could be used as an alternative to nuclear protein-coding genes. To this end, we downloaded publicly available genomes from ten molluscs (six bivalves, three gastropods, and one cephalopod) and five outgroup taxa (two annelids, one brachiopod, one phoronid, and one nemertean) and screened them for UCEs following established approaches as implemented in PhylUCE. This approach identified 4,759 UCEs shared among at least ten taxa and 325 shared across all fifteen taxa. Using a test set of the 529 UCEs with no less than 70% data completeness, we assembled and analyzed a matrix with 142,817 nucleotide positions. Maximum likelihood analysis in RAxML using the GTR+G4 model yielded a tree with strongly-supported relationships that are largely consistent with the current understanding of molluscan evolution. Thus, these preliminary results indicate that this approach has promise for resolving lingering debates about mollusc class-level phylogeny. To this end, we are expanding this dataset to include other public datasets and new genomic data from representatives of three other molluscan classes.

84-3 PADDA, SS*; GLASS, J; JOHNSON, D; STAHLSCHMIDT, ZR; U. Pacific; *s_singh40@u.pacific.edu*

Limited Supplies: Effects of water and food limitation on life history traits in an insect

Animal life histories are dependent on animals' ability to acquire resources and to invest those resources into fitness-related traits, such as growth, reproduction, and self-maintenance. Yet, animals may struggle to invest resources into several traits simultaneously due to variation in resource availability. For example, food serves as a currency for most biological processes (e.g., locomotion, reproduction, and somatic growth), and its availability exhibits spatiotemporal variation. Water is also critical to maintaining cellular homeostasis, and its availability can covary with food availability in nature (e.g., a drought can lead to a famine). The acquisition of these two resources may also be linked because water is needed to digest food. Thus, we used a 2 x 2 factorial design to investigate the independent and interactive effects of water and food limitation on life history traits using the wing-dimorphic sand field cricket *Gryllus firmus*. We placed newly molted females into two water treatment groups (water access or no access) at a constant temperature, while controlling access to dry food (food access or no access). After 5 days, we determined food consumption and survival, as well as investment into somatic and reproductive tissues. Water limitation reduced survival, investment into ovary and body mass, and food consumption. Also, food availability had a much greater effect on ovary and body mass when water was available. However, neither resource influenced investment into flight musculature, which is important for dispersal from low quality environments. Our results indicate that traits vary in their sensitivities to important resources and resource-resource interactions, and they generally demonstrate that water limitation can modulate and overwhelm the effects of food availability on investment into key life history traits.

P3-128 PADDA, SS*; GLASS, J; STAHLSCHMIDT, ZR; U. Pacific; *s_singh40@u.pacific.edu*

Effects of heat wave and water limitation in an insect—from life history to behavior and physiology

Animals live in complex environments where multiple environmental factors naturally co-vary. For instance, heat waves are often accompanied by droughts. Shifts in complex environments characterized by multiple, co-varying factors may lead animals to adjust life history (e.g., increased allocation of resources from somatic to reproductive tissues), behavior (e.g., increased dispersal or foraging) or physiology (e.g., reduced energy or water use). These biological adjustments may be cooperative. For example, combined conditions of heat wave and water limitation may result in reduced behavioral activity that, in turn, reduces energy use and water loss through respiration. Alternatively, adjustments may work antagonistically where, for example, stressful environments may result in a diversion of resources from immunity to somatic tissue. To investigate how water limitation and simulated heat waves alter life history, behavior, and physiology, we used a 2 x 2 factorial design to manipulate the thermal environment (field-parameterized heat wave or control conditions) and access to water (present or absent) in wing-dimorphic, variable field crickets *Gryllus lineaticeps* during early adulthood. After 4 days of treatment, we assayed behavioral exploration in a novel environment. We also measured rates of metabolism and evaporative water loss via flow-through respirometry, and assayed immune function (total phenoloxidase activity) in females. Last, we determined the key life history traits of survival and investment into tissue types (e.g., flight muscle status, and gonad and body mass). Our results will shed light on how complex environmental shifts influence several levels of biological organization in animals—from life history to behavior and physiology.

67-6 PADIAN, K; Univ. of California, Berkeley; *kpadian@berkeley.edu*
Launch Mechanics of Quetzalcoatlus and Other Large Pterosaurs: A Test of Three Hypotheses
There are three main hypotheses about how large pterodactyloids may have launched themselves from the ground: (1) a running takeoff in bipedal posture, (2) a standing takeoff in bipedal posture, and (3) a standing takeoff in quadrupedal posture, powered almost entirely by the forelimbs. Manipulation of fossils at the UT Austin Vertebrate Paleontology Laboratory enabled us to test these hypotheses. (1) Thrust from the legs during running must exceed stalling velocity, but wingstroke amplitude, which with wingbeat frequency determines the thrust of the wings, is limited by shoulder height, body size, and wing length. Because wing length is positively correlated with body size (and wingbeat frequency is negatively correlated), large pterosaurs could not have achieved a stroke reaching 40° below the horizontal (considered minimally effective for thrust) without leaping. So a simple running takeoff is unlikely. (2) The proximal hindlimb segments of most large pterosaurs were nearly as long as the forelimbs, and each set of bones was three times the gleno-acetabular length. The erect parasagittal hindlimbs, proportionally longer relative to body length than those of herons and egrets, needed to effect a wing-assisted jump to bring the animal to approximately three hip heights above the ground to enable a wingstroke to reach 40° below the horizontal. This appears possible, so (2) is plausible. (3) When the humerus is laterally extended, rotation effecting retraction of the forelimb is prevented by a bony stop at the deltopectoral crest. To retract the forelimb for a quadrupedal launch, it must be supinated at least 135°, and thrust must be provided by a sudden extension of the elbow and wrist joints, for which no adequate musculature is known. Hypothesis (2) appears to be the only plausible one.

MOORE-1 PADIAN, K; UC Berkeley; *kpadian@berkeley.edu*
Lessons from the "Intelligent Design" trial: Explaining evolution and climate science in a "post-evidentiary world"
To many people, we now live in a "post-evidentiary world" that rejects traditional forms of evidence and analysis in favor of preconceived dogma and culturally tribalized beliefs, whether in politics, health, education, social policy, or science. Declining acceptance of basic and applied scientific understanding has been documented for decades. But there are avenues for scientists and educators to address the underlying causes with the public, who remain largely confused about science as a form of knowledge. Scientific concepts can be explained better when listeners understand that science often uses words differently and comes to conclusions differently than other forms of human understanding do. In the Dover (PA) "Intelligent Design" trial of 2005, it was critical to convey to the presiding Judge how we think we know what we know, why method is the heart of science, why peer review is essential, why "theory" is the strongest concept in science and "fact" the weakest, why the "tentativeness" of science is not a weakness, why consilience is critical to reconstructing our knowledge of unrepeatable and complex phenomena, why science is restricted to the study of natural phenomena, and why "Intelligent Design" failed all those criteria. Scientists and educators, like public safety and health officials, can be more effective with prevention than with recovery: explaining what science is and isn't, and how it works, fosters the essential elements of critical thinking from the classroom to the courtroom.

138-2 PAGÈS, F*; FABRE, AC; HERREL, A; ABOURACHID, A; Muséum National d'Histoire Naturelle, Paris, National History Museum, London; *fanny.pages@mnhn.fr*
Morpho-functional trade-off between physiology and flying ability in birds
The hoatzin (*Opisthocomus hoazin*) is one of the only strictly folivorous birds and has a unique digestive physiology. Due to the foregut fermentation, their crop is hypertrophied which implies modifications of the scapular girdle. It has been hypothesized that it could have functional implications by greatly reducing the sternal carina thus reducing the insertion site for the flight muscles. However, this hypothesis remains to be tested. This study aims to quantify the morphology of bones that are functionally important during flight: the sternum, the scapular girdle, and the humerus. To do so, a 3D surface geometric morphometric study was performed on each bone for more than 50 species of birds with different locomotor abilities and diet. Basal metabolic rates from the literature were also used in order to test for possible functional trade-offs between physiological parameters, flying ability, and the shape of each bone. Morphological differences in relation to diet and flying ability were explored using a Principal Component Analyses, phylogenetic multivariate analysis of variance and phylogenetic partial least square regression. Our results show morphological differences for the bones of the scapular girdle depending of the type of flight and diet. No relationship was found between the metabolism and flight type and the shape of each bone even when body mass and phylogeny were taken into account. In summary, the shape of scapular girdle of birds seems a very good indicator of adaptations for flight, its shape distinguishing good and poor flyers. The sternum is an exception in being mainly impacted by centroid size. This can highlight its multiple roles ranging from the protection of the internal organs to the insertion of flight muscles.

P3-21 PALECEK, AM*; BLOB, RW; Clemson University; *apalece@g.clemson.edu*
Comparative Kinematics of Flamingos During Terrestrial Walking Versus Wading
Moving between aquatic and terrestrial habitats produces several challenges for locomotion, as animals must accommodate changes in buoyancy, drag, and substrate. Many species change locomotor behavior as they move between habitats, shifting from walking on land to swimming through water. Others, however, do not change locomotor mode and, instead, use walking in both habitats. Species such as turtles and salamanders walk while fully submerged underwater, showing locomotor patterns affected by differences in buoyancy between habitats. However, diverse species engage in wading behaviors, in which the limbs move through the water but the body is partially out of the water. We evaluated how locomotor kinematics are impacted by changes in water depth during wading by filming Chilean Flamingos (*Phoenicopterus chilensis*) at the Greenville Zoo (SC). We predicted that birds will take shorter steps in water than on land and, potentially, take the highest steps at intermediate depths. We also predicted that the head and neck would adopt a position closer to the center of mass during shorter steps in water, and that stride velocity would be slower in water than on land. Preliminary analyses suggest that strides are slower in shallow and deep water than on land, though head position and stride length were not affected by water depth. Our results suggest that flamingos adjust limb movements as they wade through deeper water, shifting from stepping over and into shallow water, to dragging the leg through deeper water when stepping above the surface becomes intractable. These data shed light on potential mechanisms that long-legged animals may use to overcome the challenges of transitioning between terrestrial and aquatic habitats.

71-5 PALERMO, NA*; THEOBALD, JC; Florida International Universtiy, Miami; *npale005@fiu.edu*

Fruit flies shift their visual attention to compensate for fast optic flow during flight.

Flying fruit flies must compensate for the visual limitations of their tiny compound eyes. Their small light-capturing aperatures admit little light, and this gets worse during flight, when images move rapidly over the retina and reflect little light to any one spot. This is especially problematic in the faster regions of the visual field, perpendicular to the direction of flight, but could be ameliorated by shifting attention forward, to slower regions of the flow field. To test for attention shifts, we measured steering responses of rigidly tethered flies during simulated forward flight in a visual arena. We found that as forward speed increased, fruit flies responded more strongly to turning cues presented directly in front, and largely ignored cues presented out to the sides. These results are consistent with a shift in attention from peripheral to forward regions, in response to high speed forward motion. We further tested if such shifts could affect other regions for other direction of optic flow, but found attention shifts only in the forward direction. This may be an adaptation to the normal flight patterns, which are characterized by long forward bouts of flight with intermittent saccades. Because the processing that mediates the attention shift seems to be direction-agnostic, the response may be trading off directional-selectivity for high-speed performance.

72-6 PALMER, R/M*; NIJHOUT, H/F; Duke University; *rayleigh.palmer@duke.edu*

Morphological Murals: The Scaling and Allometry of Butterfly Wing Patterns

Butterfly wing color patterns exhibit arguably some of the most diverse morphological traits found in nature. Color patterns are a composite of three symmetry systems: basal, central and border, each with a species-specific shape and location on the wing. Each of these systems is comprised of morphological components that are thought to be under different and independent developmental regulation. This raises an intriguing question: how does the color pattern scale with variation in wing size? Does it scale as a single coordinated unit or do individual pattern elements show independent scaling relationships? It seems reasonable to assume that in wings of different sizes the distances between the signaling centers that control the patterns will be different, and this would affect the positioning of the pattern elements. In this study, we seek to uncover the relationship between the size and position of individual pattern elements and the overall size of the wing. We analyzed the color patterns of Junonia coenia forewings and hindwings from animals reared on different diet qualities that induced substantial variation in overall size of the wing. We will describe trends of differential scaling of pattern elements across the wing as well as the scaling of the signaling sources that induce the large eyespots that characterize the color pattern of this species. To conclude, we will discuss the implications of our findings for the development and evolution of pattern element size, shape and position in the wing.

136-2 PALUH, DJ*; COLOMA, LA; BLACKBURN, DC; University of Florida, Centro Jambatu de Investigación y Conservación de Anfibios, Florida Museum of Natural History; *dpaluh@ufl.edu*

Evolutionary Lability in Life History, Morphology, and Performance in Andean Marsupial Frogs

Variation in life history traits has been hypothesized to drive many macroevolutionary patterns of morphological variation. Anurans exhibit the highest life history diversity of all terrestrial vertebrates. The ancestral, and most widespread, reproductive condition is a complex biphasic life cycle in which there is aquatic oviposition with free-swimming tadpoles that undergo a dramatic metamorphosis. Direct development (DD; lacking the tadpole stage) has repeatedly evolved to presumably release species from water-dependent reproduction. Within the Andean radiation of marsupial frogs (genus *Gastrotheca*), species have transitioned between complex (biphasic) and simple (DD) life-cycles multiple times, but the factors that promoted these transitions and the morphological consequences of these events remain unknown. We hypothesized that biphasic *Gastrotheca* species have morphologically and functionally diverged from DD *Gastrotheca* due to disparate developmental mechanisms, differential selective pressures early in ontogeny (aquatic versus terrestrial), and dependence on aquatic habitats for reproduction. Alternatively, elevation may better predict morphology due to local adaptation, as this radiation occupies an extensive altitudinal range, inhabiting lowland rainforest to alpine tundra. Using phylogenetic comparative methods, we demonstrate that life history, body form, and locomotive strategies have been evolutionarily labile in Andean *Gastrotheca*. Montane species have morphologically diverged from lowland species multiple times, regardless of reproductive mode. Montane lineages have repeatedly evolved shortened hindlimbs, small toepads, and diminished locomotive abilities compared to lowland *Gastrotheca* species. These results suggest that the life history transitions in *Gastrotheca* are decoupled from shifts in morphology and habitat-use.

126-2 PANKEY, MS*; MACARTNEY, KJ; GASTANALDI, M; GOCHFELD, DJ; SLATTERY, M; PLACHETZKI, DC; LESSER, MP; University of New Hampshire, Escuela Superior de Ciencias Marinas, University of Mississippi; *sabrina.pankey@unh.edu*

Coincident shifts in symbiotic communities underlie convergent host evolution

Microbial symbionts play crucial roles in metazoan health and have likely exerted considerable influence along evolutionary timescales. We examined the impact of microbial composition on both sponge phylogeny and trait evolution by mapping 16S variants onto a supermatrix phylogeny encompassing over 1000 sponge specimens sampled throughout the Caribbean. Similar and predictable ancestral shifts within the symbiont community both impact the tempo of host speciation and coincide with the evolution of host physiological traits. Together, these data support that microbial symbionts have significantly impacted evolution in early metazoans.

111-2 PAPASTAMATIOU, YP*; BODEY, TW; BRADLEY, D; FRIEDLANDER, AM; CASELLE, JE; FREEMAN, R; JACOBY, DMP; Florida International University, University of Auckland, University California Santa Barbara, University of Hawaii/National Geographic, University of California Santa Barbara, Zoological Society London; *ypapasta@fiu.edu*

Multiyear social stability shapes cryptic colonial behavior in an ectothermic marine predator

Colonial or highly social animals may show social stability with animals forming social bonds with the same individuals over multiple years. Often these social associations facilitate reproductive strategies, yet phenomenon of colonial sociality is primarily confined to mammals and birds. Measuring dynamic social associations in wide-ranging marine animals in the wild is a considerable challenge and therefore knowledge of social stability in such animals is largely unknown. We used acoustic telemetry and Gaussian mixture modelling to build social networks for a population of grey reef sharks at a Pacific atoll. Sharks behaved similar to central place foragers, forming daytime groups in small core areas and dispersing over larger areas at night where they increased their activity. Movement networks were used to assign membership of individuals to specific clans which were then shown to be highly socially assorted. Furthermore, the same individuals formed associations over four consecutive years. We built a series of individual based models to determine if social foraging and passive information transfer could drive the formation of such social groups in reef sharks. Models suggest that passive information transfer would provide a large advantage over solitary hunting and that passive information transfer with CPF behavior would be more advantageous than more social foraging without a home range. Our models conform to analyses where we infer social foraging information based on leadership patterns in the acoustic data. We show that ectothermic marine predators can form groups with strong social stability and that potential drivers of group formation may be related to foraging and not reproduction.

P2-7 PARK, MH*; GERSONY, JT; ROCKWELL, FE; HOLBROOK, NM; Harvard University; *mariapark@college.harvard.edu*

Leaf-Level Carbon Dynamics of Trees with Various Phloem Loading Strategies in Elevated CO_2 Conditions

Plants are integral to the functioning of the natural world. Vegetation accounts for a significant portion of global carbon fluxes into and out of the atmosphere, and the terrestrial carbon cycle's existing equilibria could become skewed by climatic changes, such as temperature increases and drought. As atmospheric CO_2 levels rise, it is critical to expand and deepen our current comprehension of how trees will respond to this shifting environmental factor. To study the effects of elevated CO_2 on plant functioning, six tree species were selected based on their different strategies of loading sugars produced by photosynthesis into their phloem transport vasculature (*phloem loading*). We hypothesize that trees dependent on a sucrose concentration gradient to load sugars into the phloem (*passive phloem loaders*) will be less efficient in sugar export in conditions of higher atmospheric CO_2 concentrations. Over the course of 24 hours, rates of net photosynthesis were measured with the Li-Cor 6400, and leaf discs collected for their dry weight. These measurements allow calculation of net C balance and thus temporal patterns of sugar export into the phloem. The observation of relative rates of sugar export in this study will improve our understanding of how trees with different phloem loading types will respond to elevated atmospheric CO_2 concentrations.

73-5 PARMENTIER, E*; RAICK, X; VIGOUROUX, R; MéLOTTE, G; Univ. of Liège, Belgium, HYDRECo, French Guiana; *E.Parmentier@ulg.ac.be*

Birth and Evolution of Acoustic Communication in Piranhas (Serrasalmidae)

Within piranhas, sound production is known in carnivorous species whereas herbivorous species were thought to be mute. As these carnivorous sonic species have a complex sonic apparatus, we hypothesise that transitional forms could be found in some serrasalmid species. We investigate sound production in different species covering all the Serrasalmidae phylogenetic tree to understand the evolution of the sonic mechanism in this family. The results highlight the evolutionary transition from a simple sound-producing mechanism without specialised sonic structures in the herbivorous species (*Piaractus* and *Myloplus*) to a sonic mechanism involving large, fast-contracting sonic muscles vibrating the swimbladder in the genera *Pygocentrus* and *Serrasalmus*. Hypaxial muscles in herbivores primarily serve locomotion, but some bundles caused sound production during swimming accelerations, meaning these muscles have gained a dual function. Sound production therefore seems to have been acquired through an exaptation event, i.e. the development of a new function (sound production) in existing structures initially shaped for a different purpose (locomotion). In further evolutionary stages (*Catoprion* and *Pygopristis*), some bundles are distinguishable from other hypaxial muscles and insert directly on the swimbladder. At this stage, the primary function (locomotion) is lost in favour of the secondary function (sound production). In the last stage (*Pygocentrus* and *Serrasalmus*), the muscles and insertion sites are larger and the innervation involves more spinal nerves, improving calling abilities. The comparison of sounds and sonic mechanisms shows the evolution of acoustic communication corresponds to a trajectory where the initial exaptation event is then subject to adaptations.

P2-28 PARRY, HA*; JOSEFSON, C; TAYLOR, HA; ANDREASEN, V; PARK, NR; HOOD, WR; KAVAZIS, AN; Auburn University; *hap0017@auburn.edu*

Immune Challenge During Reproduction has Minimal Impact on Mitochondrial Respiration and Oxidative Stress

To meet the demands of an immune challenge during reproduction, a female is theorized to reduce the allocation of resources to reproduction or limit allocation to maintenance. We determined if female mice are exposed to an immune challenge (keyhole limpet haemocyanin; KLH) during reproduction, they experience a reduction in mitochondrial performance and increase in oxidative stress. Laboratory mice were paired with a male until just before giving birth and randomly assigned to one of three groups. Female mice in the control group (LC) were injected with saline 2 days after parturition, and then sacrificed 1 week after weaning. In the lactating immune challenge group (LI), females were treated similarly except they were injected with KLH. Finally, in the pregnant-lactating immune challenge group (PLI), females were treated the same as LI group, except the male was left in the box with the female until 3 days post-partum, so the female was pregnant while lactating. The second litter was born within 3 days of weaning, immediately removed, and females were sacrificed 1 week later. No significant differences were observed in liver or hindlimb skeletal muscle mitochondrial coupling as measured by the respiratory control ratio (RCR). Isolated mitochondrial reactive oxygen species emission in the skeletal muscle was significantly lower in LI compared to LC, but no differences were observed in the liver. Skeletal muscle PGC1-α was significantly reduced in LI mice compared to LC. We also observed various changes in antioxidant protein levels in both tissues. In conclusion, an immune challenge during reproduction has an impact on females that is organ specific and varies with the intensity of the demand.

P2-216 PARSONS, ZM*; ST. PIERRE, R; BERGBREITER, S; University of Wyoming, University of Maryland, University of Maryland ; *zparsons@uwyo.edu*

Towards Understanding the Role of Resilin in Arthropod Springs and its Applications to Microrobotics

Small insects repeatedly jump with high take-off velocities by storing elastic energy in springs from deformation of the exoskeleton. These jumps allow insects to navigate rough terrain, clearing obstacles many times their own size, making them sources of inspiration in microrobots. However, at-scale microrobots lack the agility of insects, in part due to limited understanding of energy storage in the exoskeleton of insects. Insect springs are often composites of stiff chitin and compliant resilin, with a difference in Young's Modulus over three orders of magnitude. The resilin contributes very little to the springs' stored elastic energy, so its role is unclear. To explore the role of 'soft' materials in springs, the insect spring was simplified to a synthetic analog, a bilayer cantilever beam. We explored the dynamic and failure properties of the springs both experimentally and theoretically. Dynamic properties of the spring did not vary significantly with varying thickness of soft material, but ultimate stored elastic energy did; springs with thicker soft material stored more energy through increased deflection. However, mass-specific stored energy in composite springs decreased, though the mass of insect springs is negligible compared to body mass. Theoretical exploration shows a stark contrast in the design sensitivity of stored potential energy to material thickness. Potential energy storage is less sensitive to soft material thickness in composite springs than the thickness of single material springs, so any mistakes in soft material thickness are negligible compared to mistakes in hard material; this facilitates designing a greater reliability in jumping robots while sacrificing little performance, a key trait for the success of autonomous robots.

104-5 PARSONS, ZM*; HERNDON, JD; STRANGE, JP; LOZIER, JD; DILLON, ME; University of Wyoming, Utah State University, University of Alabama; *zparsons@uwyo.edu*

Altitudinal variation in flight morphology and kinematics of common-garden reared bumblebees (Bombus vosnesenskii)

Altitudinal shifts present a potential means of tracking optimal temperatures over short geographic distances in response to warming climates. Although upslope shifts may allow organisms to escape rising temperatures, decreased air density at higher elevations increases aerodynamic and energetic costs of flight, potentially restricting upslope shifts for flying organisms. However, fliers could compensate for low air density through changes in morphology and kinematics. Bumblebees collected from high elevations have relatively larger wings than those from low elevations, likely to facilitate flight in thinner air. But whether such morphological changes result from developmental plasticity or adaptation is unknown. We caught queen *Bombus vosnesesnkii* from low (70 m asl) and high (1475 m asl) elevation sites in Oregon, USA. We reared colonies from these queens in common-garden conditions in the laboratory and then subsequently measured flight morphology and kinematics in high elevation (2100 m) conditions. We will discuss how morphology (body mass, wing area, and wing moments) differ between common-garden reared and field-collected bumblebees and how differences in morphology alter flight kinematics during hovering flight. Finally, we use a simplified aerodynamic model to estimate differences in energetics of flight between low and high elevation bees.

S3-7 PATEK, S. N.; Duke University; *snp2@duke.edu*

The power of extreme movement: evolution, behavior, and biomechanics of mantis shrimp strikes

The biomechanics of fast mantis shrimp (Stomatopoda) strikes involves an uneven and extreme flow of energy from muscle contraction, spring-loading, latch-release, to a final, intense impact. Slowly-contracting, force-modified muscles load springs that are controlled by latches. These slowly-loaded springs ultimately drive the extraordinary accelerations of mantis shrimp strikes - shifting actuation from muscle to a springy material. Here I examine how extremely fast biological systems, particularly mantis shrimp, offer an insightful lens on fundamental issues in integrative, organismal biology, facilitated by features such as the spatial and temporal separation of the muscle, spring, latch, and weapon. I consider the implications of extreme movement in behavioral contexts ranging from fights to feeding, and across multiple scales of analysis ranging from individual variation in behavior on up to the tempo and mode of evolutionary change. Nonetheless, these systems present significant challenges, such as requiring exceptional technology for visualizing movements over sub-millisecond and millimeter scales, and obtaining measurements of the power output of elastic structures. The burgeoning interest in biomimetics and bioinspiration, alongside a growing field of evolutionary biomechanics, is propelling forward integrative and interdisciplinary insights from extreme biological movements.

13-5 PATEL, RN*; CRONIN, TW; Univ. of Maryland, Baltimore County; *rickp1@umbc.edu*

Celestial and Idiothetic Compasses in a Path Integrating Mantis Shrimp

Stomatopods, better known as mantis shrimp, are predatory crustaceans which commonly inhabit holes in benthic marine environments for use as burrows. Many stomatopod species forage at extended distances from these burrows before returning back to their homes, risking predation. Previous work had uncovered that the mantis shrimp, *Neogonodactlyus oerstedii* use landmark navigation in parallel with a path integration system to efficiently return to their burrows after foraging. Path integration requires an animal to possess a compass sense to infer its orientation in space and an odometer to measure the distance it travels in given directions. In order to begin to discern what compass cues inform the path integrator of *N. oerstedii*, individuals were placed in circular arenas under open skies with their burrows hidden from view. During foraging, animals were rotated 180 degrees on platforms placed in the center of these circular arenas. Under clear and partly cloudy skies, rotated animals exhibited homeward paths oriented towards the burrow despite being passively rotated. In contrast, under heavily overcast skies, rotated animals exhibited homeward paths oriented in the opposite direction of the burrow. These results indicate that *N. oerstedii* uses a celestial compass when available. However, when celestial cues are obscured, *N. oerstedii* appears to rely on an idiothetic (internally referenced) compass during path integration. Future work will aim to uncover which specific cues inform the celestial and idiothetic compasses of *N. oerstedii*.

P1-211 PATTERSON, LN*; HARRIS, BD; COVI, JA; Univ. of North Carolina at Wilmington; *lnp7743@uncw.edu*
Tiny, but Mighty! Zooplankton, the Missing Link in Assessments of Ecosystem Health for Waters Near Coal-fired Power Plants
Most zooplankton species in inland lakes exploit a life cycle with active life stages occupying the water column and dormant life stages resting in the bottom sediment. Because of this pelagic-benthic coupling, monitoring zooplankton communities in both locations can provide a powerful view of the health of lake ecosystems. The primary objective of the present study was to assess the state of the active zooplankton community in a cooling-water source (Lake Sutton, North Carolina) for a former coal-fired power plant by monitoring zooplankton diversity and abundance in the water column. The secondary objective was to assess the presence of zooplankton embryos in the benthos by identifying dormant life stages of crustacean zooplankton in sediment basins. The present study demonstrated that (1) the diversity of the active zooplankton community decreased over the last 30 years, (2) few zooplankton species have predictable succession patterns over the course of a year, (3) early life stages of copepods are the most common crustacean zooplankton in the water column, and (4) the diversity of embryos in the sediment is extremely low. Together, the decrease in diversity and low recruitment of some species to adulthood indicate that zooplankton in Lake Sutton face serious spatially heterogeneous challenges to recruitment from dormant egg banks that jeopardize community stability, and, in turn, the long-term viability of recreational fish stocks. Managers of freshwater resources should take note; maintaining a stable zooplankton community may decrease the cost of maintaining important recreational fish stocks.

S9-5 PAUL, VJ*; FREEMAN, CJ; AGARWAL, V; Smithsonian Institution, Georgia Institute of Technology; *paul@si.edu*
Chemical Ecology of Marine Sponges
The chemical ecology and chemical defenses of sponges have been investigated for decades; consequently, sponges are among the best understood marine organisms in terms of their chemical ecology, from the level of molecules to ecosystems. Over ten thousands natural products have been reported from marine sponges, and although relatively few of these sponge compounds have been studied for their ecological functions, they have been demonstrated to serve as chemical defenses against predators, microorganisms, fouling organisms and other competitors. Sponges are hosts to an unrivaled diversity of microorganisms, with over 30 microbial phyla found in these associations to date. Microbial community composition and abundance is highly variable across host taxa, with a continuum from diverse assemblages of many microbial taxa to those that are dominated by a single microbial group. Microbial communities expand the nutritional repertoire of their hosts by providing access to inorganic and dissolved sources of nutrients. Not only does this continuum of microorganism-sponge associations lead to divergent nutritional characteristics in sponges, these associated microorganisms and symbionts have long been suspected, and are now known, to biosynthesize some of the natural products found in sponges. Modern ‘omics' tools provide ways to study these sponge-microbe associations that would have been difficult even a decade ago. Metabolomics facilitate comparisons of sponge compounds produced within and among taxa, and metagenomics and metatranscriptomics provide tools to understand the biology of host-microbe associations and the biosynthesis of ecologically relevant natural products.

P3-91 PAULSON, DM*; PATTERSON, LN; COVI, JA; Univ. of North Carolina at Wilmington; *dp1865@uncw.edu*
Using Model Species to Explain the Effects of Coal Combustion Residual Contamination on a Zooplankton Community
Recent data have shown that Lake Sutton contains an unstable zooplankton community that has decreased dramatically in biodiversity over the last three decades. This lake is a cooling reservoir contaminated with coal combustion residuals, which could be responsible for the current biological issues in the lake. Because cladocerans are one of the only zooplankton that show predictable patterns of abundance in the lake, we hypothesized that cladocerans have developed a natural resistance to toxicants in the lake. If that is true, non-native species will be impacted by putative toxicants in water and sediment collected from Lake Sutton. The present study addresses this by testing the susceptibility of the non-native cladoceran, *Daphnia magna*, and brine shrimp, *Artemia franciscana*, to native water and sediment from Lake Sutton. Toxicology protocols approved by the Environmental Protection Agency (EPA) test exposures of active zooplankton to putative environmental toxicants, but no standardized protocols address exposures of zooplankton during embryonic dormancy. In addition to testing the water using a standard EPA protocol for larvae of *D. magna*, ephippia of *D. magna* and dechorionated embryos of *A. franciscana* were exposed to Lake Sutton water and sediment during dormancy and early post-dormancy development. Exposure to Lake Sutton water did not increase mortality during early development in either species but did induce some abnormal development in *A. franciscana*. However, exposure of embryos to sediment from the lake during the hatching process caused high larval mortality. These data may explain why daphnids are one of the few stable zooplankton left in Lake Sutton.

P1-146 PAYNE, AA*; HORR, DM; JOHNSON, MA; Trinity University; *apayne2@trinity.edu*
Tail Autotomy in Lizards Not Associated with Tail Use Behaviors or Energy Storage
In many lizard species, the ability to autotomize the tail allows for immediate survival in the face of predation, but may come at a high cost. Tails are often used in communication and energy storage, and so tail autotomy can thus decrease an individual's overall fitness. In this study, we examine this tradeoff in species that use the tail differently. We predict less frequent tail autotomy in species that use the tail for social display or energy storage, as a full tail is particularly valuable. In species that primarily display the tail in a predatory context, we predict the frequency of tail loss will be higher, as the tail is made especially vulnerable to autotomization. We studied seven 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*), Texas spiny lizards (*Sceloporus olivaceus*), and Texas spotted whiptails (*Aspidoscelis gularis*) 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 approximated energetic content of the tail using the ratio of tail mass to body mass. We found that the frequency of tail autotomy varies from 20 to 60 percent of individuals across the seven species, and lizards that use their tail in a social context also tend to do so in a predatory context. In preliminary analyses, there is no clear relationship between the frequency of tail autotomy and the use of the tail in social, predatory, or energetic contexts.

63-3 PEELE, EE*; SULIKOWSKI, J; YOPAK, KE; University of North Carolina Wilmington, University of New England; *eep5093@uncw.edu*

Hot Brains: The Effect of Temperature on Brain Development in the Little Skate (Leucoraja erinacea)

Cartilaginous fishes experience indeterminate growth, where both brain and body grow continually throughout their lives. This characteristic suggests that environmental conditions may impact overall development of the brain. Since neural growth has been linked with life history traits such as life span, reproductive output, mate selection, ability to avoid predators and find prey, changes in brain size and/or brain organization can have functional implications on the fitness consequences of environmental change in these species. The effects of increased rearing temperature were studied on brain development in the little skate (*Leucoraja erinacea*). Eggs cases were collected from a breeding stock of *L. erinacea* and placed into either ambient or 5° above ambient seawater conditions, and neonates were placed into a nursery tank at the same rearing temperature after hatching. To better understand how brain size and organization may be affected after exposure to increased temperatures, brains were imaged using magnetic resonance imaging (MRI) and brain region volumes were compared between the two treatment groups. Trends indicate differences in brain size between treatment groups and are particularly localized to the telencephalon and olfactory bulbs ($F_{1,15} = 4.56$, $p<0.05$). Results from behavioral studies of neonate *L. erinacea* were combined with neuroanatomical data to study the possible connection between increased rearing temperature and behavioral abnormalities in these skates. Determining the effects of increased temperature on neural phenotype and behavior aids in understanding the consequences of environmental stressors on brain development in this species and will indicate how they may fare in a changing climate.

P3-160 PEKAR, KJ*; ONTHANK, KL; Walla Walla University; *katherine.pekar@wallawalla.edu*

Diet analysis of the burrowing octopus Muusoctopus leioderma using stable isotopes and sequencing

As dietary generalists, octopuses play an important role in food webs, with their dietary intake directly impacting many other organisms in their ecosystem. However, traditional analyses of octopus diets rely on middens, or the hard-shelled remains of prey items that are left behind in dens. As a result, studies on octopuses' diets are likely biased against soft-bodied prey items, which may result in a misunderstanding of their ecological impact. Little is known about the diet of *Muusoctopus leioderma*, a deep-water octopus that was recently observed at 10 meters depth. *Muusoctopus leioderma* is a nocturnal octopus that spends daylight hours burrowed into muddy substrate, meaning that no middens are produced. They are also difficult to feed and keep in the lab, limiting current understanding of their diet. These factors make this novel, shallow-water population of *M. leioderma* an excellent candidate for two alternate dietary inquiries: stable isotope analysis, which can be used to provide general clues about long term diet, and genetic analysis of fecal material, which can provide specific insight into a few dietary components. Together, these methods not only provide information about the diet of *M. leioderma*, but also present new methods that may be used to supplement current ecological understanding of octopuses.

P1-184 PELLICANO, A*; AZIEVA, G; LYNCH, KS; Hofstra University; *apelli4@pride.hofstra.edu*

Eavesdropping on heterospecifics: Does it modify reproductive physiology in female brood parasites

Social regulation of reproductive hormones is a means by which conspecific males and females orchestrate successful reproductive efforts. We investigate whether social cues modify activity within the hypothalamic-pituitary-gonadal (HPG) axis and the specificity of this response in a social parasite that is known to eavesdrop on the communication signals of other species: the brown-headed cowbird (Molothrus ater). Brown-headed cowbirds are obligate brood parasites that do not build nests or care for their own young. Instead, obligate brood parasites leave their eggs in the nest of a host species and therefore must coordinate their breeding attempts with conspecifics as well as potential heterospecific hosts. Here, we explore whether the vocal signals of potential host species can also be used as a social cue that modifies the HPG axis of female brown-headed cowbirds. Results reveal that both conspecific and heterospecific song-exposed females exhibit significantly greater circulating estradiol concentrations as compared to silence-exposed females. While conspecific song induces the greatest elevation in circulating estradiol, there is no significant difference in circulating estradiol levels in females exposed to either conspecific or heterospecific songs. This pattern suggests both song types are effective at evoking a reproductive physiological response. On the other hand, circulating progesterone concentrations did not differ among the song- and silence-exposed groups nor did the size of the female's ovarian follicles. These results indicate that heterospecific vocal communication signals can effectively be used as a social cue that simultaneously provides necessary information regarding breeding status of hosts and modifies breeding condition of the eavesdropper.

90-4 PENNEY, CM*; BURNESS, G; WILSON, CC; Environmental and Life Sciences Graduate Program, Trent University, Peterborough, Ontario, K9J 7B8, Department of Biology, Trent University, Peterborough, Ontario, K9J 7B8, Ontario Ministry of Natural Resources, Trent University, Peterborough, Ontario, K9J 7B8; *chantellepenney@trentu.ca*

Transgenerational effects of elevated temperature on the upper thermal tolerance of lake trout and brook trout

Global average temperature is rising, however, the capacity of ectotherms to cope with climate change isn't thoroughly understood. Some can respond to long-term changes in temperature through transgenerational plasticity (i.e. thermal experiences can be passed on to offspring, improving their ability to tolerate warmer temperatures). Previous studies have observed this in fish that are warm-adapted or eurythermal, but it's unclear whether cold-adapted, stenothermal ectotherms are capable of the same response. This study examines transgenerational plasticity in lake trout and brook trout to determine whether there's potential for these fish to cope with anticipated warming. If transgenerational plasticity is possible in cold-adapted, stenothermal ectotherms, then trout will be better suited to a warmer environment if their parents had also experienced a warm environment. To test this, we acclimated adult trout to optimal or elevated temperatures, then crossed these fish to produce offspring from parents of matched and mismatched temperatures. At the fry stage, the offspring were also acclimated to an optimal or elevated temperature and their thermal tolerance was determined by measuring their critical thermal maximum and metabolic rate during an acute temperature challenge. Transgenerational plasticity was evident in both species since offspring performed best when their environment matched that of their parents. Future experiments will explore the influence of transgenerational plasticity on proximate mechanisms underlying thermal tolerance.

P2-239 PENROD, LM; Florida Institute of Technology; *lpenrod2011@my.fit.edu*
Geographic Distribution of Fishes with Cranial Spines
Over the past several decades, research has investigated the role of spines in many forms of life. In most cases, the role of spines is to prevent predation, but what about the small, spine-like, projections on the cranium of fish? These spines and ridges vary in shape and size across species, and are unlikely to be anti-predatory. Before investigating the functional role cranial spines play in the life of fishes, we must understand how these fish interact with their environment. Specifically, we must know where these fish reside and what environmental factors are associated with their presence. I identified over 400 species around the world that exhibit this trait. Spatial models highlight a species richness in the North Sea while predictive models indicate that depth, temperature, productivity, and current are significantly related to the presence of fish with cranial spines. After reviewing the results, we believe that the function of these spines may be related to current.

S2-11 PEPIN, Kim, M.*; WEBB, Colleen, T.; WILBER, Mark, Q.; National Wildlife Research Center, Fort Collins, Colorado State University, Fort Collins; *kim.m.pepin@aphis.usda.gov*
Scaling individual-level immunology to the population level provides risk assessment from convenience samples
Infections in most animal species cause an antibody response that can be captured with a model of within-host antibody kinetics. Individual-level variation in the deterministic infection curve can be quantified using antibody quantity data from individuals sampled over time with known infection times. This variation and prediction of the infection curve then can be used to infer time of infection in serosurveillance samples collected once from individuals with unknown times of infection. With estimates of infections times, it is possible to derive important population-level metrics for risk assessment such as force of infection - the rate that susceptible individuals become infected - and understand how risk changes in time. We apply this approach to convenience samples of antibodies to influenza A in feral swine to determine seasonality in disease risk and spatial spreading patterns. We compare our individual-based method of inferring population-level processes to risk assessment methods that use seroprevalence analyses (a common method of assessing spatio-temporal patterns of risk using serosurveillance data). Inference of seasonal risk dynamics and spatial spreading using the individual-based approach differ from seroprevalence analyses. The seroprevalence patterns are tightly coupled to the sampling design, but our individual-level approach allows for inference of spatio-temporal risk patterns that differ from the sampling design. Our analyses demonstrate a method for improving risk assessment in wildlife disease surveillance programs, and can be used to improve our understanding of the role of individual-level variation in driving disease dynamics.

31-3 PERAMBA, K. B.; EDSINGER, E.*; Marine Biological Laboratory; *eedsinger@mbl.edu*
Imaging the neuromuscular systems of cephalopod arms and suckers.
The boneless bodies of octopus, squid, and other cephalopods owe their structural integrity and functional diversity in part to exquisitely arranged muscle fibers that permeate, shape, and power the body. The arms and suckers of octopus, for instance, are exceptional in both prehensile dexterity and in strength. The suckers themselves are highly engineered modular structures that operate individually but also act with local coordination, each sucker having its own little ganglion that wires into an overhead nerve cord running through the arm. The suckers are mechanical in their suction and also serve tactile and chemosensory functions. The sophistication, modularity, and hierarchy of the arms and suckers system, and its potential interface with neuroscience, biomechanics, and robotics is enticing but powerful tools for live and whole-mount imaging are largely unestablished. Recent advances in microscope systems, dyes, and clearing agents enable imaging of sub-cellular structure in the context of gross anatomical features, for instance, the muscle fibers and ganglia of entire arm suckers in octopus hatchlings. Here we characterize the spatial arrangement of nerves and muscles in whole-mount arms of different species of cephalopods using fluorescent dye and label-free methods and various imaging approaches, including confocal, light sheet, and polarized light microscopy. In addition, we develop a behavioral assay to capture sucker dynamics of octopus hatchlings during the process of grip and release from a substrate, a first step to enabling readouts of neural and muscular activity in suckers using genetically encoded fluorescent biosensors, like GCaMP to visualize calcium dynamics.

P3-69 PERAMBA, K. B.*; NASH, C.; WALTERS, D.; HACKWORTH, L.; SCHUMM, M.; PINEDA, O.; EDSINGER, E.; The Marine Biological Laboratory, The University of Chicago; *kperamba@mbl.edu*
Squid Monday: Characterizing population structure in Doryteuthis pealeii
One thing I've learned growing up on Cape Cod is that like tourists in the summer, *Doryteuthis pealeii* will also come and go. Since spending more time on the water in Nantucket and Vineyard Sound this year, I have begun to notice complex seasonal patterns of local squid in size, sexual maturation and lifespan but year-round dynamics remain poorly understood and possible underlying genetic structure is contentious. The species occurs from New Foundland to the Gulf of Venezuela and is fished commercially from Southern Georges Bank to Cape Hatteras, including a long-standing fisheries here in Woods Hole and the Cape Cod region. During summer the Long Fin Inshore squid inhabit the waters close to shore but then go offshore in winter. Beginning in early May there is a distinct size class of very large and sexually mature *D. pealeii* but then by late July mature females are half the size, and potentially have half the lifespan. To characterize genetic structure within the local squid we sampled 30 animals of different size classes once a week for 16 weeks and once a month thereafter. Weight, length, gonad maturity, and sex identification were assessed as well as two arm tips per animal were collected and frozen for sequencing. With over 500 samples, we were able to extract DNA and generate two data sets commonly used in population genetics, microsatellites, expanding on previous work by others, and mitochondrial control region sequencing, which offers potentially greater signal for resolving any genetic structure over time.

S1-8 PEREDO, EL*; CARDON, ZG; Marine Biological Laboratory; *elperedo@mbl.edu*

Calm vs. panicked: contrasting responses of desert-derived and aquatic green microalgae during desiccation and rehydration

Desiccation tolerance in the vegetative state (DT) is an essential adaptive trait for colonization of land. DT has evolved independently in multiple lineages of terrestrial green algae, including in the algal ancestor of all seed plants. Scenedesmaceae is a particularly powerful group of microalgae for the study of DT because the group includes multiple, independently-evolved desert-dwelling species and very closely-related aquatic taxa. Desiccated desert algae recover photosynthetic activity immediately when rehydrated, whereas their aquatic relatives display very limited to no recovery upon rehydration. Desert-evolved taxa also minimize accumulation of reactive oxygen species during water loss. Gene expression patterns during desiccation and rehydration reveal that during desiccation, desiccation-tolerant taxa first downregulate photosynthesis and energetic metabolism then notably increase expression of genes and transcription factors traditionally associated with stress in the broad green plant clade, including Late Embryogenesis Abundant proteins, small Heat Shock Proteins and oxidoreductases. The controlled response in desert-evolved taxa contrasts with an overall upregulation of gene expression observed in the aquatic taxa, consistent with a state of cellular emergency during desiccation. These data suggest that desiccation tolerance may rely on both the coordinated expression of multiple (potentially ancient) genes and pathways protecting cellular structures from damage, and the induction of regulatory networks that control an ordered cellular shutdown under unfavorable conditions. The shift towards a more quiescent metabolism during stress might be as important for DT as the induced expression of well-recognized, stress-related proteins.

58-3 PEREZ, LK*; KWIATKOWSKI, MA; GUMM, JM; Stephen F. Austin State University, Stephen F. Austin State University; USFWS; *leahperez93@gmail.com*

Opsin Diversity in Anurans

Among major vertebrate groups, anurans are understudied with regards to their visual systems and how they function. In this study, we sampled North American anurans representing diverse evolutionary and life histories and which likely possess visual systems adapted to meet different ecological needs. Using standard molecular techniques, we obtained sequences for rhodopsin (Rh1) and three cone opsins (LWS, SWS1, and SWS2A) expressed in anuran retinas. Changes to the amino acid sequence of opsins can result in shifts in the wavelength sensitivity of a visual pigment and thus can alter dim-light and color vision. We identified variable sites, including those with polarity changes, by comparing specific amino acid positions across taxa. Variation within the transmembrane regions of each opsin indicate possible spectral tuning sites, suggesting variation in dim-light and color vision among anuran clades. Current phylogenetics do not fully explain patterns of anuran opsin evolution. Preliminary results suggest that selective pressures relating to ecology and light environment may be driving changes to anuran visual systems. This work provides an exciting framework to further our understanding of anuran vision.

P2-280 PEREZ-GALVEZ, FR*; TEETS, NM; University of Kentucky; *fernan954@gmail.com*

Genetic and Environmental Factors Influencing the Efficacy of Transgenic Sterile Insect Technique

Sterile Insect Technique (SIT) is a strategy for controlling insect pest populations in which sterilized males incapable of siring offspring are released into the environment. Transgenic technologies have the potential to improve SIT operations by providing new strategies for sterilization and sex sorting through the use of conditional lethality constructs. The conditional lethality systems that have been developed are tetracycline suppressible such that flies with tetracycline in their diet are able to develop and breed normally under laboratory conditions. Once in the wild, where tetracycline is absent, lethality is triggered by stage- or sex-specific developmental disruption. However, the extent to which environmental and genetic factors affect the expression and activity of these conditionally lethal transgenes has not been assessed. Before such transgenic strategies can be incorporated into management programs, information regarding the efficiency and potential environmental impacts is urgently needed. Here, using *Drosophila melanogaster* as a model, we are evaluating intrinsic (genetic variability) and extrinsic (environmental variability) factors that may jeopardize the effectiveness of transgenic SIT release programs. In this poster, we will present egg viability assays for transgenic SIT as a proof of concept and preliminary data from a quantitative gene expression assay targeting the transgenic construct. Moreover, we are constructing a dose response curve for the conditional lethality system along a tetracycline concentration gradient. Beyond our focus on SIT, these experiments also have broader implications for assessing risks associated with the use of genetically modified organisms in natural and agricultural ecosystems.

38-5 PEREZ-GUERRA, D*; GARDUÑO-PAZ, MV; MENDEZ-SANCHEZ, JF; ADAMS, CE; Midwestern State University, Facultad de Ciencias, Universidad Autónoma del Estado de México, Scottish Centre for Ecology and the Natural Environment, Glasgow University; *evo.david-przgr@hotmail.com*

Morphological plasticity in Girardinichthys multiradiatus: a high-altitude fish endemic to Upper Lerma, Mexico

Phenotypic plasticity is any change in the characteristics of an organism in response to a signal from the environment. These differences in morphology are important because they provide information on survival strategies of organisms. Morphological variation induced by the consumption of different prey seems to be common in fish, expanding the threshold of possible prey in a limited environment. *Girardinichthys multiradiatus* is a viviparous species endemic to the Lerma river basin, unique due to its confined distribution and abundance. We determined the morphological variation of *Girardinichthys multiradiatus* induced by two types of diets: *Hyalella* sp. and *Daphnia* sp. of two different populations of the Alto Lerma Basin. For the determination of morphology, the captured organisms subjected to two months of experimentation were photographed and analyzed with using geometric morphometry. The results showed that individuals fed *Hyalella* developed thin bodies, compact eyes, compact heads, thin caudal peduncles and they tend to thin out towards the caudal fin. In contrast, individuals that were fed *Daphnia* have robust bodies, large eyes, robust heads, robust caudal peduncles and they tend to widen toward the caudal fin. These morphotypes correspond to effective morphologies related to optimal efficiency of predation of benthic and limnetic organisms and to optimal swimming efficiency for hunting them, which shows a plastic response in *G. multiradiatus* explaining the survival of the species in unfavorable habitats.

P1-206 PERNET, B*; SILVERMAN, E.R.; VALENTICH-SCOTT, P; PERNET, Bruno; California State University Long Beach, Smith College, Santa Barbara Museum of Natural History;
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The seashells of an iconic public artwork: diversity and provenance of the mollusks of the Watts Towers

The structures of the Watts Towers (WT), an iconic Los Angeles artwork created by Sabato Rodia in 1921-1954, are covered with mosaics that include thousands of mollusk shells. Little is known about the diversity or sources of these shells, though such information would be of great utility to WT conservators and to art historians. We documented the diversity of mollusk shells present in the WT and used data on the ranges and habitats of the species, and other characteristics of the shells, to make inferences about their provenance. We identified shells of 34 species of mollusks in the WT, 24 of them bivalves and 10 gastropods. Almost all (29/34) of these species are native to southern California shorelines, especially those of bays and estuaries. Rodia could have accessed these sites on foot, by automobile, or by using the extensive network of Red Car trolleys. Some of the bivalve shells on the structures bear complete drill holes made by naticid gastropods, suggesting that the shells were collected post-mortem, presumably after they had washed up on beaches. These observations are consistent with the sparse documentary evidence on the origin of the shells of the WT. We also discuss the potential origins of the five species not native to California shorelines found on the WT. These data on the diversity of the seashells of the WT should be very useful for conservators, and also of interest to scholars of and visitors to the WT.

139-6 PETERS, JM*; MAHADEVAN, L; Harvard University;
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Distributed control of ventilation by honeybee-inspired robots

Honeybees actively ventilate their nests by flapping their wings at the entrance of the hive in response to high air temperatures. Individual bees respond only to local temperatures but collectively they are able to coordinate large-scale, efficient flows by separating inflow and outflow in space. This spatial separation arises not due to direct communication or coordination between bees, but due to the interaction between distributed fanning behavior, airflow and temperature. We designed a system of honeybee-inspired robots composed of temperature sensors, DC fans, and analog control circuitry. We distributed these robots at the entrance of a heated chamber and quantified the behavior of the robots, the flow they collectively generate and the temperature profile along the entrance of the chamber during ventilation bouts. This artificial system allows us to experimentally probe questions related to the physical mechanisms of self-organization in this system, which are difficult to observe in the honeybee system.

140-2 PETERSEN, JC*; RAMSAY, JB; Westfield State University;
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Walking on Chains: Anatomy and Functional Morphology of the Walking Appendages in Sea-Robins

Fish fin rays (lepidotrichia) are typically composed of paired and segmented structures (hemitrichia) that help support and change the shape of the fins to affect water flow. Yet, marine fish that are members of the family Priontinae (sea-robins) have specialized pectoral fin rays that are separated from the pectoral fin and used like limbs to walk along the seafloor. While previous kinematic studies have supported the use of these specialized fin rays as walking appendages, there is little information on how the morphology of the "walking-rays" and associated muscles facilitate underwater walking. Here we examine the musculoskeletal anatomy and flexibility of the walking-rays and pectoral fin rays in two species of sea robin, Prionotus evolans and P. carolinus using gross dissection, microCT, and materials testing. Our main goals were to determine what structural modifications may be present in the walking rays that would promote the use of these flexible chain-link rays as supportive structures capable of propelling the fish forward along the seafloor. Our results revealed enlarged processes for muscle attachment and novel S-shaped bone segments forming the dorsal hemitrich of the walking rays. The three-point bending tests of the walking fin rays revealed a significant reduction in flexibility when bent dorsally or rostrocaudally. This increased rigidity rostrocaudally may support the ray once it is depressed into the seafloor and enters the propulsive phase. The novel S-shape segments of the hemitrichs may also promote the directional rigidity of the walking rays of sea-robins. These novel features, which are also used for prey detection, may have allowed these benthic fish to conserve energy while foraging on the seafloor. Furthermore, the features of the ray morphology may be applicable in robotics or the development new lightweight prosthetics.

40-7 PETERSON, AN*; MCHENRY, MJ; Univ. of California, Irvine; *anpeter1@uci.edu*

The Coupled Strategies of Lionfish and Prey Fish

During predation, the interplay of predator and prey behaviors determine the outcome of an interaction. These interactions are guided by the coupled strategies of both animals, which are difficult to determine through observation alone. To examine the relationships between predator and prey strategies, we used a combination of experiments and mathematical modeling of red lionfish (*Pterois volitans*) as they pursued green chromis (*Chromis viridis*). The lionfish used a pure pursuit strategy, where they attempted to maintain a zero bearing regardless of prey maneuvers. The green chromis were capable of swimming faster than the lionfish but generally exhibited avoidance swimming only when the lionfish moved within a close threshold distance. Kinematics of observed behaviors validated our computational model, which we used to evaluate the strategies of both predator and prey. This approach has the potential to offer a framework for understanding predator-prey interactions in a diversity of animals.

8-4 PFEIFFENBERGER, JA*; TYTELL, ED; Tufts University; *Janne.Pfeiffenberger@Tufts.edu*

Ontogenetic scaling of the viscoelastic mechanical properties of the body of the bluegill sunfish, Lepomis macrochirus

The bodies of fishes are composed of flexible materials that interact mechanically with the fluid around the fish. While the behavior and mechanics of fish swimming have been studied for decades, few studies have investigated the role of internal body mechanics in swimming performance. Fish generate propulsive forces by activating muscles that bend their bodies from side to side. The internal viscoelastic body mechanics therefore determine how effectively these muscle forces can produce whole-body propulsive forces. In this study, we measured the viscoelastic mechanical properties of the bodies of bluegill sunfish, *Lepomis machrochirus*, over a range of sizes, from 65 to 170 mm SL. We used an oscillatory bending apparatus in which fish were connected to a servomotor, while the other end of the fish were attached to a six-axis force transducer. The bodies were then bent back and forth at different frequencies (1 - 7 Hz) and amplitudes (2.5, 5, 7.5, 10, 12.5, and 15 degrees) while body torques were measured with the force transducer. We made these measurements at two body regions: between the 1st and 3rd dorsal fin ray and between the 1st and 3rd anal fin ray. We aim to answer several questions, including (1) does the fish body have a resonant frequency?, (2) do the body regions differ mechanically?, and (3) How do these properties change across ontogeny? We found that body torques increased with increasing amplitude, but remained unchanged across frequencies, indicating that the body does not have a resonant frequency in the range of normal swimming frequencies. Local flexural stiffness on the other hand increase with frequency, but remained unchanged with increasing amplitudes. Both body torques and local flexural stiffness increased with increasing body size.

P1-16 PFEIFFENBERGER, J.A.*; DONATELLI, C.M.; MEKDARA, P.J.; FATH, M.J.; KHANNA, S.; SHEN, T.H.; TYTELL, E.D.; Tufts Univ.; *eric.tytell@tufts.edu*

Design your own fish! Engaging museum visitors in biomechanics research

Most people enjoy watching colorful fish swim, and they may have even wondered about all the different varieties of fishes, but few people get to participate in the biomechanical research that is helping us understand the diversity of fishes. The goal of this project was to make this process more accessible by engaging museum goers in the research itself. We have developed a prototype for a "Design a Fish" activity, an exhibit that will allow science museum visitors to create their own flexible model of a fish from an assortment of tail and body parts of varying shapes and flexibilities. The fish can then race down a long tank against those of other museum goers, with sensors in the tank recording the speed, kinematics, and body properties of each fish. Preliminary tests show that body shape and flexibility both play a part in a model's speed, although the two factors interact in a complex way. By allowing the public to contribute to the creation and testing of the model fish, we make the complicated processes behind fish locomotion tangible, while simultaneously developing a source of crowdsourced data to quantify the effect of shape and flexibility on swimming performance in fish. To accompany the exhibit, we designed videos that illustrate particle image velocimetry (PIV), a laboratory technique used to quantify fluid flow patterns around swimming fish. We combined animation, clever writing, and science to explain PIV and how we use it to study fish swimming. We hope museum visitors gain a deeper understanding the techniques and scientific process used to study swimming in fish and animal movement in general.

P2-168 PHILLIPS, HA*; KANE, EA; Georgia Southern University; *hp01174@georgiasouthern.edu*

Do Generalists Specialize? Potential for Individual Variation in Trinidadian Guppy Feeding Kinematics

Local adaptation is a phenomenon observed across a variety of species in which populations develop behavioral, morphological, and physiological traits which help them survive in their environment. Trinidadian guppies, *Poecilia reticulata*, are a model for studies of local adaptation. Upstream low predation (LP) populations experience higher population density and lower resource availability compared to downstream high predation (HP) populations. Differences in prey selection, feeding rate, and cranial morphology between populations indicate that feeding kinematics may be a locally adapted trait, however, recent work does not support this hypothesis at a population level. We hypothesize that within dense low predation populations, individuals may be driven to specialize to avoid resource competition, leading to differences in feeding kinematics that are not observable between populations. Using wild caught female guppies from replicate rivers, feeding kinematics were measured for three videos per fish then analyzed to determine how individuals vary when compared to their respective populations. Individuals in at least one HP population tend to specialize, contradicting expectations that intraspecific competition may drive specialization. Because this effect is not correlated to high predation or low predation groups, this suggests that individual specialization can occur, but is not necessarily repeatable across similar environments and may not reflect local adaptation of populations. While local adaptation is present in other physical and behavioral traits, it is likely that a generalist approach to feeding is more advantageous for guppies at both the individual and population levels.

40-2 PHILSON, CS*; FOLTZ, SL; DAVIS, JE; Radford University; *cphilson@radford.edu*

Plasticity in Songbird's Environment-Behavior Interactions at a Supplemental Feeder

Identifying the nature of a songbird's behavioral response to dynamic environmental conditions may help us understand their potential to cope with future environmental change. In this study, we compared the ambient environmental conditions during a species' "normal" feeding behaviors to the conditions during displacement behaviors (an uncommon event where a bird removes another bird from the feeding perch). Our results show house sparrows (Passer domesticus) have the largest degree of variation in environmental conditions between normal and displacement feeding events, while eastern-tufted titmice (Baeolophus bicolor) have the least of the seven species studied. We also identified relationships between environmental conditions and specific species-species displacement encounters. Overall, these results help us map the nature of interactions between the environment and the behavioral plasticity of songbirds via this uncommon, but potentially important behavior.

P2-253 PIRRONE, M*; NARICI, V; BARNHART, D; MASS, S; SUNY New Paltz; *pirronem1@hawkmail.newpaltz.edu*
Comparing the Kinematics of Metamorphosed Axolotls and Tiger Salamanders
Axolotls are neotenic ambystomoids which are closely related to North American tiger salamanders. Though axolotls generally remain aquatic, there are rare cases of spontaneous metamorphosis where they become terrestrial. While metamorphosed axolotls appear very similar to other terrestrial ambystomoids, there are significant differences in the functionality of the metamorphosed axolotls which are poorly understood due to the rarity of the metamorphosis. Initial inspection of the terrestrial axolotls indicate that they have issues in locomotion and coordination. Are there developmental timing windows not met by the axolotls, which may cause metamorphosed axolotls to be less adapted to terrestrial locomotion? This study is examining the potential differences of the functional morphology that occur developmentally. In particular, high speed cinematography was used to observe the kinematics of the salamanders. Particular physical landmarks on the salamanders were marked, tracked, and analyzed to compare movement and function. Variables such as velocity, acceleration, and jerk were examined and compared. Initial analysis of the data showed that metamorphosed axolotls had greater amplitudes of acceleration and greater jerk (the rate of change of acceleration), meaning their movement is less smooth and balanced. This is indicative of lower efficiency and less coordination in metamorphosed axolotls than tiger salamanders.

P2-76 PLATFOOT, K. E.*; SATTERLIE, R. A.; University of North Carolina, Wilmington; *kep1294@uncw.edu*
Neuromodulatory Innervation of the Buccal Cone Muscles of the Pteropod Mollusk, Clione limacina
The pteropod mollusk *Clione limacina* is a holoplanktonic gymnosome found in the northern Pacific and Atlantic Oceans as well as the Arctic Ocean. Its relatively complex behavioral hierarchy, which includes various swim states and feeding and reproductive behaviors, is supported by a simple, easily accessible central nervous system which makes it an ideal model organism for neurobiological studies. The buccal cones of *Clione* serve as hunting tentacles and contain three types of muscle tissue: smooth circular, smooth longitudinal, and striated longitudinal. The smooth circular muscle is responsible for buccal cone extrusion and the smooth and striated longitudinal muscles are believed to be involved in buccal cone retraction and prey manipulation, respectively. Several neurotransmitters and neuropeptides have been found to have modulatory effects on hunting behaviors including FMRFamide, serotonin, small cardioactive peptide b (SCP_b), myomodulin, and buccalin. However, the distribution of these modulators relative to the muscle layers is unknown. This study uses immunohistochemistry at the light and transmission electron microscopy (TEM) levels to identify and describe contact locations within the buccal cones. FMRFamide, SCP_b, myomodulin, and buccalin are found near the orally-concentrated, striated longitudinal muscles, while of serotonin can be seen at the bases of adhesive papillae. Synapses between SCP_b reactive neurons and striated longitudinal muscles have been observed with TEM. These results provide further insight into the function of the buccal cone longitudinal muscles relative to the behavioral control of prey acquisition.

P1-229 PLEE, TA*; POMORY, CM; University of West Florida; *taraplee4@gmail.com*
Sea Cucumbers and Sand Dollars as Biomonitors for Nearshore Environments
Plastic production has been continually growing worldwide due to its high durability, low cost, and light weight. Microplastics are either intentionally created, or derived from larger plastic sources via mechanical, photolytic, or chemical degradation. Microplastics can adsorb contaminants and persist in the ocean, often settling in the sediment. This may pose problems for benthic marine organisms that ingest small particles, such as sand dollars and sea cucumbers. Sand dollars (Echinodermata: Echinoidea: Clypeasteroida) are microphagous feeders ingesting particles, and occur in high densities in nearshore sandy environments altering the sediment through bioturbation. Sea cucumbers (Echinodermata: Holothuroidea: Holothuriida/Aspidochirotida) are deposit feeders ingesting sediment in seagrass and sandy habitats. This study had four goals: first, to examine if sediment where sand dollars and sea cucumbers were collected contain microplastics; second, to examine if *Mellita tenuis*, a common sand dollar in the northern Gulf of Mexico, ingests microplastics in two locations along the panhandle of Florida, U.S.A.; third, to determine if sea cucumbers (*Holothuria floridana*, *Holothuria mexicana*, and *Actinopyga agassizi*) ingests microplastics in two locations along the Florida Keys, U.S.A.; and fourth, to conduct a laboratory experiment to examine if *M. tenuis* will ingest microbeads. Sediment samples contained a variety of microplastics, mainly fibers and fragments. *Mellita tenuis* and all three species of sea cucumbers ingested microplastics of different sizes and shapes similar to the microplastics extracted from the collected sediment, which may make them useful as a monitoring tool for nearshore sandy environments.

112-3 PODOLSKY, RD; College of Charleston; *podolskyr@cofc.edu*
Sensitivity of Dynein-ATPase to pH in Sperm of the Sea Urchin Arbacia punctulata
External fertilization exposes gametes to variation in environmental conditions, including temporal and spatial variation in seawater pH. Gametes may be especially vulnerable to changes in pH because they are small and lack homeostatic capacities. In addition, sperm of many organisms rely on a mechanism of suppression in the testes that is regulated by the presence of high CO2/low pH. As a result, sperm are naturally pre-disposed to be sensitive to low seawater pH, which can pose a risk to fertilization under acidified conditions by reducing sperm activity. Our work with sea urchins has demonstrated that near-future (50-100 y) predicted changes in seawater pH reduce sperm motility and fertilization success, and that these effects vary between populations. To address one mechanism that could underlie this effect, I examined the pH sensitivity of dynein, a microtubule-associated ATPase that regulates energy use by sea urchin sperm. Using a microassay of inorganic phosphate production, I tested kinetics and stability of dynein under a set of pH and temperature conditions, using sperm from two populations of the sea urchin *Arbacia punctulata* from different latitudes. Dynein was highly sensitive to pH within a range that included near-future predicted conditions and that showed negative effects on sperm motility and fertilization. Populations differed in the sensitivity of dynein to pH and temperature. Dynein is therefore one component of sperm physiology that appears susceptible to ocean acidification, providing a possible mechanism that connects effects at the molecular level to whole organism performance.

98-5 POFF, M*; OWERKOWICZ, T; California State University, San Bernardino; *poff.ma@gmail.com*

Ablation of rostral conchae does not affect heat exchange in the upper respiratory tract of the domestic chicken

Respiratory turbinates in the nasal cavities of endothermic vertebrates are known to play an important role in heat conservation and dissipation. In birds, cartilaginous rostral and middle conchae protrude inward from the nasal capsule, increasing the surface area of the respiratory epithelium, decreasing the distance to the respiratory airstream, and thus improving the efficiency of heat and water exchange. How important either of the conchae is to heat conservation at low ambient temperatures and dissipation at high temperatures is not known. To determine the role of the rostral concha, we performed a bilateral surgical excision in hatchlings of the domestic chicken, and sham operated control animals. We measured exhaled air temperatures in adult chickens (n=5 per treatment) under mild sedation across a 10-40°C range and at 30% relative humidity. With the animals breathing with a closed beak, there were no significant differences in exhaled air temperatures at the external nares between experimental and control animals at any of the tested ambient temperatures. When breathing with an open beak, exhaled air temperatures at the glottis were significantly different only at ambient 40°C, with the experimental animals having a slightly (1.0°C) warmer breath, but also a slightly higher (0.9°C) core temperature (t-test, $p<0.05$). Our results suggest that either the rostral concha does not participate in heat exchange in the nasal cavity, or the middle concha compensates for the loss of its rostral counterpart. Loss of the rostral concha may exert an effect on the trachea's ability to dissipate heat at high ambient temperatures, but does not improve its countercurrent exchange at low temperatures.

14-1 POORBOY, DM*; BOWERS, EK; SAKALUK, SK; THOMPSON, CF; BOWDEN, RM; Illinois State University, University of Memphis; *dpoorbo@ilstu.edu*

Experimental cross-fostering of eggs reveals effects of territory quality on reproductive allocation

Parental and territory quality are often correlated in birds, and both factors influence the resources allocated to offspring. Surprisingly, the relative contribution of these two components of parental investment remains obscure. We experimentally decoupled the normal covariation between parental quality and territory quality to test the hypothesis that territory quality influences prenatal and postnatal reproductive allocation. Territories were categorized into low-, intermediate-, and high-quality based on fledging success of nesting attempts in nestboxes over a previous 6 year period. To decouple covariation between territory quality and individual quality, nestbox entrance size was increased on high-quality territories and left small on poor-quality sites because house wrens (*Troglodytes aedon*) prefer small over large entrances to their nest sites. We found a significant prenatal effect of territory quality on nestling provisioning: when reared on intermediate-quality territories, nestlings hatching from eggs produced on low-quality territories were provisioned at a higher rate than those hatching from eggs produced on high-quality territories. We propose that the increased provisioning was brought about by increased nestling begging mediated by a maternally derived compound transferred to the eggs of stressed females in poor-quality habitat.

P2-251 POPP, M*; WAINWRIGHT, DK; LAUDER, GV; Harvard Univ.; *glauder@oeb.harvard.edu*

Thresher Shark Tails: Denticle Morphology in Comparison to Other Pelagic Sharks

Shark skin denticles (scales) are diverse in morphology both among species and on the body of single individuals although the function of this diversity is not well understood. Current views indicate that denticles may both reduce drag and increase thrust during swimming, and the morphology of denticles on different regions of a shark may reflect local flow conditions. We systematically measured denticle morphology on the caudal fin of thresher sharks (genus *Alopias*), and compared thresher tail denticles to those of selected other pelagic shark species. Thresher shark tails are equal in length to the rest of their body and are uniquely used for both locomotion and hunting (by whipping the tail over their head into schools of fish). Using surface profilometry, we quantified 3D denticle patterning and texture in three adult and two embryonic threshers at 27 regions in the adults and 16 regions in embryos. We then measured a suite of variables using these 3D surfaces to compare the surfaces of different regions. The tails of thresher embryos have a membrane that covers the denticles and reduces surface roughness: membrane surface roughness is 4µm, while embryo denticle roughness averages 10 µm. In adult thresher tails, denticles are generally similar to those of other pelagic shark tails, and there is no gradient in roughness from the base to the tip of the tail: tail skin roughness averaged 9 µm. All along the tail there is a leading-to-trailing edge gradient with leading edge denticles larger and lacking ridges (average roughness = 9 µm), while trailing edge denticles are smaller, with 5 ridges, and an average roughness of 7 µm. We found no evidence that the increased undulatory excursions from the base to the tip of thresher tails correlate with surface roughness.

P3-187 POPSUJ, SE*; SEAVER, EC; Agnes Scott College, University of Florida Whitney Laboratory of Marine Bioscience; *spopsuj@agnesscott.edu*

Investigation of Wnt signaling during posterior regeneration of the annelid Capitella teleta

Wnt signaling is a common pathway used in development and has been shown to be important for whole-body regeneration. The phylum Annelida is an important taxon to study because there are varying capabilities in whole-body regeneration. Furthermore, with new technologies, functional studies are possible in annelids.We hypothesized Wnt signaling would be important in the regeneration of the annelid *Capitella teleta*, which can undergo posterior regeneration. In this study, we assessed how inhibition and activation of Wnt signaling during the early stages of regeneration affected regenerative success in *C. teleta*. We pre-exposed animals to known concentrations of C-59, ETC-159 and Alsterpaullone, commercially available inhibitors and activators of Wnt signaling. After thirty-six hours of pre-exposure, we amputated worms and monitored their regenerative success for three to seven days. Animals were continuously exposed to one of the drugs for the duration of the experiment, and the drug was exchanged every twenty-four hours. Control specimens were amputated under the same conditions but in filtered sea water without a drug. All treatments used antibiotics to minimize bacterial invasion. Regenerative success was assessed on the basis of morphology and a cell proliferation assay. Originally, we predicted that inhibition and activation of wnt signaling would result in no regeneration and increased regenerative ability, respectively. Our preliminary results suggest inhibition of wnt signaling is not critical during early stages of regeneration in *C. teleta*. This work will provide insight into the mechanisms controlling the early stages of regeneration and repatterning in *C. teleta*, and will contribute to a larger understanding of the role of wnt signaling in regeneration.

P2-164 PORTER, N; JOST, JA*; Bradley University; *jjost@bradley.edu*

Examining potential links between temperature stress and antioxidants in the invasive zebra mussel

Since being introduced to the US, the invasive zebra mussel has rapidly spread throughout freshwater ecosystems. Zebra mussels cause extensive damage by harming native species and altering water quality, and they are extremely costly to remove from the hard surfaces to which they attach. Therefore, there is great interest in understanding their physiology in an attempt to limit, or at least predict, spread to new habitats. A previous experiment in our lab indicated energy imbalances are occurring during acute cold exposure. One possible explanation is that cold temperatures increased oxidative stress and impaired ATP production. While previous studies suggest reactive oxygen species increase in zebra mussels due to elevated metal concentration, high salinity, and pesticides, little is known about the links between temperature and oxidative stress in this species. Therefore, the specific aims of this project were to determine whether the invasive zebra mussel experiences oxidative stress during thermal fluctuations, and if so, which antioxidant is most active. We exposed zebra mussels to a cold stress in the lab by progressively decreasing water temperature from ambient river temperatures of 26°C to 10°C over three hours. Tissue was collected to determine superoxide dismutase activity, total antioxidant capacity, and the levels of TBARS. No significant changes in total antioxidant capacity or TBARS were seen, but superoxide dismutase activity increased after 12 hours at 10°C. We are currently using qPCR to expand these data to include the mRNA levels of superoxide dismutase, metallothionein, and catalase over time during this acute cold exposure.

46-3 POS, KM*; KOLMANN, MA; GAO, TR; GIDMARK, NJ; Univ. of Massachusetts Lowell, George Washington University, University of Chicago, Knox College; *kelsie_pos@student.uml.edu*

Evolutionary history versus dietary niche as factors shaping pharyngeal jaw structure in cyprinid fishes

Anatomy is the product of both evolutionary history and environmental pressures. The family Cyprinidae (order Cypriniformes) is a hugely diverse group of fishes, 300 of which are endemic to North America. The oral jaw of minnows is edentulous and the entirety of mechanical prey processing occurs via the pharyngeal jaws. Individuals from this clade feed on myriad prey and occupy nearly all freshwater habitats, making them a phenomenal model system for studying the interplay between diet and evolutionary history in shaping anatomy. Here, we used micro-computed tomographic (CT) imaging of 243 species of North American minnows to evaluate how anatomical specialization, evolutionary history, and dietary ecology have shaped morphology in this clade. We utilized phylogenetic data established for this clade, linear landmark-based metrics, and geometric morphometric shape analyses to capture anatomical variation and compare morphological diversity. We see trophic convergence among genera, and considerable variation in morphology of several traits: 1) muscle attachment area (a proxy for muscle force); 2) relative size of the ligament spanning left and right hemi-mandibles (a proxy for strength and range of motion and skeletal flexibility); and 3) jaw elongation (a proxy for gape). These functionally important metrics of bone (hemi-mandibles) and ligament were negatively correlated yet they evolve independently. Moreover, there is extensive overlap in morphospace, suggesting that convergence is widespread among minnow dietary guilds. Our results show a recent burst in diversification with most variation occurring at the extant tips of the phylogenetic tree for both functional and geometric morphometric traits.

36-2 POTTS, LJ*; TEETS, NM; Univ. of Kentucky ; *lesliej.potts@gmail.com*

Overwintering Spiders: Physiological Responses to the Winter Season

Winter provides many challenges for terrestrial arthropods. Low temperature, freeze-thaw cycles, precipitation and extreme weather events negatively impact the survival and fitness of these organisms. Most arthropods overwinter in a dormant diapause state and cease functions like activity, growth, and feeding. However, a select few arthropods remain active during winter, and the ability to maintain activity and continue foraging and growing are thought to provide a selective advantage by enhancing spring reproduction. In this study, we investigated physiological and biochemical adaptations to winter conditions in a winter active wolf spider, Schizocosa stridulans. For this species and other winter active arthropods, winter activity requires the capacity to maintain locomotion at low temperatures, preserve energy balance with limited food availability, and tolerate extreme cold events. We hypothesized that winter activity in S. stridulans is accompanied by a low critical thermal minimum (CTmin) and the ability to grow and maintain energy balance in the winter. We tested CTmin of spiders kept in experimental incubators in the lab. It is much lower than other recorded spiders or insect taxa, averaging -4˚C. We show that these spiders are able to continuing growing throughout the winter, with a field-collected dataset, and that nutrient profiles reflect that growth with increased levels of protein across the winter months and a decrease in lipids. In ongoing analyses, we are using metabolomics to identify putative cryoprotectants and other metabolic changes that may support winter activity. Taken together, this work provides critical insights into the physiological and biochemical adaptations that permit this spider to be among the small handful of species that remain active in winter.

95-7 POWERS, SD*; GRAYSON, KL; MARTINEZ, E; AGOSTA, SJ; Virginia Commonwealth University, University of Richmond, Eastern Illinois University ; *powerssd3@vcu.edu*

Ontogenetic Variation in Metabolic Rate-Temperature Relationships in Larvae of an Invasive Ectotherm

Predicting the response of organisms to environmental change requires a mechanistic understanding of physiological performance, including how it varies with ontogeny. We present data on the thermal sensitivity of mass specific resting metabolic rate (RMR_m) in five larval instars of a laboratory strain of the invasive gypsy moth (*Lymantria dispar*). Available data for this relationship are often limited to a particular life stage or age group and are measured over a narrow range of temperatures that does not encompass the temperature at which metabolic rate is maximized (T_{max}). As a result, predictive models may simply assume that metabolic rate increases with temperature over the "normal" physiological range and that the slope of the relationship between metabolic rate and temperature is invariant within species. In each instar, we observed that across a wide range of physiologically relevant temperatures (13-38°C), RMR_m reached T_{max} around 31°C and then decreased as temperature continued to increase. We found similar estimates of T_{max} across instars and similar thermal sensitivities (slopes). The exception was the 1st instar, which exhibited higher thermal sensitivities on both sides of T_{max}. Overall, the relationship between RMR_m and temperature was similar, but not invariant across the larval stage. This type of information can help provide a mechanistic understanding of how organisms respond to their thermal environments, including how invasive species like gypsy moth spread across the landscape.

P1-108 POWERS, MJ*; WILSON, AE; HEINE, KB; HILL, GE; Auburn University , Auburn Univeristy, Auburn University; *mjp0044@tigermail.auburn.edu*

A Meta-analysis of Patterns of Mate Choice in Copepods

Marine copepods are an excellent model system in which to study mate assessment. Mate choice is well-documented in copepods, and a variety of approaches have been used to instigate copepod choosing behavior. However, while the end-product of copepod mate choice has been studied in a variety of experimental situations and it is now well established that chemosensation plays an important role in copepod mating decisions, the role of other criteria in copepod mating decisions remains unclear. Using powerful meta-analytical tools and current software built for modern phylogenetic analysis, we confirm that across class Copepoda, choice of mates is a commonly observed behavior. A strong signal for mate choice persists when controlling for phylogenetic relationships between species, genera and orders. The inclusion of a phylogenetic control allows us to reliably compare the magnitude of recorded mate discrimination in diverse groups of copepods with different life history parameters, feeding behaviors, and ecological niches. We investigated the influence of experimental design on copepod mating behavior including assessments of the different types of stimuli that were employed and the density of individuals in the test environments. Critically, we grouped individual types of stimuli together under categories of criteria that copepods use to partition among potential mates, and we used these categories to investigate the strength and patterns of mate choice behavior. Although we found evidence for mate choice across comparisons, we also observed that mate choice can be influenced both by unique ecological and experimental factors. The compiled evidence in our meta-analysis suggests that copepods choose mates using multi-leveled criteria including assessment of species identity, discrimination at the population level, and, possibly, choice between mates of variable individual quality.

10-3 POWERS, AK*; BERNING, DJ; MANNING, A; NZOBIGEZA, N; GROSS, JB; Harvard Medical School, Univ. of Cincinnati; *amanda_powers@hms.harvard.edu*

Sensing in the dark: asymmetrical skulls may help blind cavefish find their way

The colonization of extreme environments is typically accompanied by extreme morphological changes. Life in complete darkness has driven the evolution of a suite of troglobitic features in the blind Mexican cavefish (*Astyanax mexicanus*), such as eye and pigment loss. While regressive evolution is a hallmark of obligate cave-dwelling organisms, putatively adaptive, constructive traits commonly arise as well. Here, we combine quantitative analysis with behavioral studies to begin to characterize mechanosensory neuromast patterning and function in the cavefish cranium. Previously, we discovered that cavefish harbor numerous cranial bone asymmetries: fluctuating asymmetry of individual dermal bones and directional asymmetry in a dorso-cranial bend of the skull biased toward the left. This asymmetry is mirrored by the asymmetrical patterning of cranial neuromasts. We explored the relationship between facial bones and neuromasts using *in vivo* fluorescent co-labeling, micro-computed tomography, and quantitative trait loci (QTL) association studies. We found an increase in neuromast density within dermal bone boundaries across three distinct populations of cavefish compared to surface-dwelling fish. We reasoned that a bend in the dorsal region of the skull may expose more neuromasts to water flow on the opposite side of the face, thus enhancing sensory input and spatial mapping in the dark. We tested this using a behavioral assay to assess swimming direction in fish with a leftward bend in the skull compared to fish with no bend. Our results suggest that facial asymmetry may have evolved as a mechanism to enhance sensory input in the absence of light.

P2-98 PRADO, DMA*; GOMES, FR; MADELAIRE, CB; SÃO PAULO STATE UNIVERSITY, Assis, UNIVERSITY OF SÃO PAULO; *meyer.unesp@gmail.com*

How Corticosterone Treatment Affects Testosterone Levels, Spermatogenesis and Wound Healing in the American Bullfrog

During reproductive season, males display high testosterone (T) levels that develop and maintain secondary sexual traits. Glucocorticoid (GC) hormones also have an important role during this period, recruiting energy stores to cope with reproductive costs. Nevertheless, the increase of CORT levels for extended periods of time can be deleterious for reproduction, diminishing T concentration and spermatogenesis. The GC also modulates immune response and may act as a mediator in the conflict of investment between immunity and reproduction. Our question is how the increase of acute and chronic increase of CORT levels interacts with spermatogenesis status, T levels and wound healing rate in the American Bullfrog (*Lithobates catesbianus*) during their reproductive season. Males were bought from a commercial farm, habituated for 7 days in individual plastic boxes and randomly divided into four groups: 1. Placebo (daily treated with sesame oil), 2. Acute CORT (daily treated with CORT solution [2µg]), 3. Operated sham (empty silastic tubes) and 4. Operated CORT (silastic tubes filled with CORT). After animals recovered from surgery, their legs were punctured with a biopsy needle. The wound was photographed and measured every 2 days in a stereomicroscopy and image analyzer software. Blood samples were collected during the experiment in order to measure CORT and T levels. Afterwards, animals were euthanized and testicles were dissected and fixed for histological analysis. T concentration, germinative cysts diameter and gonadal maturation stage will be compared between groups and correlated with CORT plasma levels and with wound healing rate.

132-5 PRAKASH, M; COYLE, SM*; FLAUM, E; LI, H; KRISHNAMURTHY, D; Stanford University; *scoyle@stanford.edu*

Coupled Active Systems Encode Emergent Behavioral Dynamics of the Unicellular Predator Lacrymaria olor

Multiple active systems in a cell work together to produce sophisticated cellular behaviors such as motility and search. However, it is often unclear how this coupling specifies the complex emergent dynamics that define such behaviors. As a model system, we analyzed the hunting strategy of *Lacrymaria olor*, a unicellular predatory ciliate that uses extreme morphological changes to extend, contract and whip an apparent "cell neck" over many body lengths to capture prey. Tracking millions of unique subcellular morphologies over time revealed that these fast dynamics encode a comprehensive local search behavior apparent only at longer timescales. This hunting behavior emerges as a tug-of-war between active sub-cellular structures that use surface cilia and cortex contractility to deform the structure of the neck. The resulting search space can be described mathematically using a small number of normal shape modes that change amplitude rapidly during hunts. The distribution of these shape modes in space and time reveals a transition point between tense and compressed neck morphologies at the mean neck length, such that new shapes are readily sampled by repeatedly extending and retracting across this critical length. Molecular perturbations to the cell-signaling controller show that coupling between ciliary and contractile programs is needed to maintain this length/shape relationship; neither system alone provides the dynamic repertoire of shapes necessary for comprehensive search. Our results highlight the utility of coupling antagonistic active systems as a strategy for encoding or engineering complex behaviors in molecular machines.

86-7 PRAKASH, V.N.*; BULL, M.S.; PRAKASH, M.; Stanford University; *vprakash@stanford.edu*

Epithelial Tissue Fracture and Healing Dynamics Govern Fast and Extreme Plastic Shape Changes in Trichoplax adhaerens

Epithelial tissues typically act as barriers and provide support to organs and embryos, but during development, these tissues also display a dynamic, fluid-like behavior. During morphogenesis, epithelial tissues undergo both elastic (reversible) and plastic (irreversible) shape changes often characterized by local cell rearrangement mechanisms such as intercalation and rosette formation, which are primarily orchestrated by genetic programs (e.g. *drosophila*). Here, we have discovered a novel fracture-based mechanism by which epithelial tissues can exhibit fast and extreme plastic shape changes in a simple, flat, early divergent animal - *Trichoplax adhaerens*. These animals continuously glide on substrates using ciliary traction to generate mechanical forces - which lead to real-time organismal shape changes and also induce local stresses in the tissue. The epithelium is surprisingly able to sustain local physiological fracture holes (~min), which can either enlarge or 'heal' (~hr), resulting in permanent plastic shape change and topological cell rearrangement, with similarities to actomyosin purse-string healing. We employ live microscopy, novel bead-based tagging and engineering mechanics analysis to quantitatively demonstrate how forces mainly govern tissue fractures. We also use agent-based active elastic sheet models & simulations to uncover how 'soft zones' in tissues are created to enable morphological solid-to-liquid tissue transitions. We reveal how tissue fractures and healing play a critical role in the entire life cycle of these animals - during their (i) continuous shape change, and (ii) asexual reproduction, where an individual animal 'splits into two' by binary fission.

P1-133 PRATER, CM*; CARR, JA; Texas Tech University; *christine.prater@ttu.edu*

Corticotropin-releasing factor (CRF) does not influence basal or depolarized GABA release from tectal neurons in Xenopus laevis

The 41 amino acid peptide CRF reduces food intake and related behaviors by acting on tectal CRFR1 receptors in the African clawed frog *Xenopus laevis* . Precisely how CRF acts within the optic tectum to inhibit food intake is unclear but may involve inhibitory GABAergic interneurons. We predicted that if tectal CRFR1-induced inhibition of food intake is mediated via inhibitory GABAergic interneurons, that exogenous CRF would increase basal and evoked GABA release from tectal explants *in-vitro*. Tectal explants from *X. laevis* were depolarized with 60 mM K+ and GABA was measured in the medium after derivatization using high-performance liquid chromatography coupled to electrochemical detection. GABA secretion from *X. laevis* tectal explants increased under depolarizing conditions and this evoked release was eliminated in calcium-free medium. Exposure of tectal explants to ovine CRF doses ranging from 1 nM to 1 micromolar (AnaSpec, Inc., Fremont, CA; 0, 0.001, 0.01, 0.1, 1 µM) had no effect on either basal or depolarization-induced GABA release. We conclude that our *in-vitro* assay measures calcium-dependent evoked GABA release from tectal explants and that CRF does not appear to influence basal or evoked GABA release *in-vitro*. These findings do not support a role for GABAergic interneurons in mediating tectal CRFR1 inhibition of food intake. Supported by a grant National Science Foundation IOS #1656734.

128-5 PRAVIN, S*; HAN, E; JAEGER, H; HSIEH, ST; Temple University, The University of Chicago; *tuh04350@temple.edu*

Toe Spacing Induces Particle Jamming During Intrusion Into Granular Media

Legged, terrestrial animals use a variety of foot shapes for moving across diverse terrain. Granular substrates such as sand, snow and cobbles display complex behavior that can range from solid to fluid in a step. The effects of foot morphology on the dynamics of interaction between feet and granular substrates remain poorly understood. The goal of this study was to characterize the effect of toe spacing on foot-ground interactions. To this end, we measured the force response to the intrusion of two parallel square rods into dry poppy seeds while varying rod gap spacing. This interaction was also numerically simulated using the discrete element method (LIGGGHTS®), and the total force on the two intruders was calculated. We hypothesized that total force would decrease as the gap between the two rods increased, with the greatest force produced at a zero gap. Our results show, however, that a peak in the total force occurs at a gap of ~3 particle diameters, which was 20 % greater than the force at large separation (>11 particle diameters), beyond which total produced force plateaued. We propose that this peak in force is the result of particle jamming between the two intruders. To quantify the degree of particle jamming, interparticle forces at different gaps were calculated. As expected, the total number of strong forces—identified as force chains—in the particle domains indicated greater particle jamming at gaps surrounding the peak force. These findings indicate that gap size between toes can significantly affect total force response to granular intrusion, and particle jamming can play a determining role in identifying the optimal gap spacing between toes to maximize force response.

P1-143 PREISING, G.A.*; O'ROURKE, C.; RENN, S.C.P.; Reed College; *gapreisin@reed.edu*

Optimization of Cresyl-Stained Brain Micropunch Technique: Investigating the Genetic Regulation of Behavior in Astatotilapia burtoni

Astatotilapia burtoni is a model organism for the study of metabolic dysregulation and starvation behaviors. This model is particularly interesting because while mouthbrooding, females undergo a self-induced starvation that represents a physiological adaptation in that the neural regulation differs from that associated with simple food deprivation. Prior research shows that differential expression of genes involved in neuropeptide signaling between brain regions may account for self-induced starvation behaviors in brooding *A. burtoni*. To study this, mRNA must be extracted and compared between brain regions; however, precise methods such as laser capture microdissection sacrifice RNA quality. We aimed to optimize a technique that isolates discrete brain regions while preserving mRNA integrity. Brain punches isolated using our modified Cresyl-staining technique had significantly higher RIN values than whole-brain tissue isolated and stored in RNALater, and non-significantly higher RIN values than unstained control punches. These refinements offer a potentially more effective way of studying mRNA expression from small target regions.

P1-234 PRESNELL, JS*; WEIS, VM; Oregon State University; *presneja@oregonstate.edu*

Characterization of Scavenger Receptor and TSR-domain Genes During the Onset and Establishment of Symbiosis in the Sea Anemone Exaiptasia pallida

Onset and establishment of cnidarian-dinoflagellate symbiosis is mediated by the host innate immune system through interpartner signaling between host receptors and symbiont surface proteins. For example, in Aiptasia (*Exaiptasia pallida*), a sea anemone that is widely used as a model for cnidarian-dinoflagellate symbiosis, it is known that symbiont glycan and host lectin binding is crucial for symbiont specificity. Additionally, evidence has shown that the scavenger receptor (SR) and TSR-domain protein signaling pathways mediate symbiont re-colonization in aposymbiotic Aiptasia. In these studies, inhibition of the SR and TSR domains caused a reduction in symbiont colonization success. However, the Aiptasia genome encodes many SR and TSR-domain genes, thus it is unclear which specific genes are directly involved in mediating symbiosis. In general, the causal genetic mechanisms underlying onset and establishment of symbiosis in Aiptasia are still largely unknown, mostly due to the lack of tools and techniques for assessing gene function in the context of symbiosis. Here we discuss our efforts in developing molecular genetic tools (e.g., CRISPR/Cas9 genome editing) to investigate the role of candidate SR and TSR-domain genes in mediating the onset and establishment of symbiosis in Aiptasia.

S7-11 PRICE, SA*; CORN, KA; FRIEDMAN, ST; LAROUCHE, O; MARTINEZ, CM; ZAPFE, K; WAINWRIGHT, PC; Clemson University, Univ. of California, Davis; *sprice6@clemson.edu*

The fish shapes project. Harnessing the power of data science, museum collections and undergraduate researchers to quantify body shape evolution across teleost fishes.

Teleosts account for 96% of all fish species, nearly half of extant vertebrate diversity, and exhibit a spectacular variety of body forms from deep-bodied moonfish to elongate eels. However, attempts to comprehensively explore general patterns in the relationship between body shape, functional morphology and ecology across teleosts have been limited by data availability. We present a morphological dataset of eight functionally relevant size and shape variables, combining length, depth and width measurements as well as seven fin spine length measurements on more than 13000 specimens from 6000+ species in the Smithsonian National Museum of Natural History collections. The resulting morphospace spans the phylogenetic diversity of teleosts and encompasses 90% of extant families and 96% of living orders. Integral to the data collection were our 30+ undergraduate researchers, who spent 18 months immersed in a coordinated research experience. When analyzed in a phylogenetic framework our data enables us to identify the primary axes of shape diversification across teleosts, describe trends in shape diversity over time and identify combinations of shape and ecological, environmental and functionally relevant biological traits that are common, rare or not found in nature. Our initial analyses indicate that the primary axes of variation and the effect of specific ecological traits on rates of morphological evolution are highly dependent on the taxonomic scale of the analyses. This highlights the difficulty of inferring global macroevolutionary patterns from smaller scale analyses and vice versa.

P3-84 PRIOR, J/H*; WHITAKER, J/M; JANOSIK, A/M; University of West Florida; *jp74@students.uwf.edu*

An Exploration of the Epigenetic Effects of Microplastics Exposure on the Common Mysid Shrimp, Americamysis bahia

Microplastics are degraded or manufactured plastic particles <5 mm in diameter. Microplastics pollution has become commonly and publicly recognized as a ubiquitous issue of environmental concern in water systems. Zooplankton of biological and commercial importance, including the easily cultured mysid shrimp, *Americamysis bahia*, have been documented to be primary consumers of microplastics. Toxins and plastics aggregate in these primary consumers, which leads to bioaccumulation in consumers further up the trophic ladder. In the presence of certain environmental stressors gene expression may be altered without changing the sequence of the DNA. One way this occurs is through methylation of the DNA, in which a methyl group can bind to the nucleotide base pairs, commonly a cytosine-guanine sequence. In different situations, DNA methylation has shown to be both short-term and reversible or permanent and potentially heritable. Microplastics exposure is a potential and increasingly common source of environmental stress. Using a Polymerase Chain Reaction (PCR) based technique known as Methylation Specific-Amplified Fragment Length Polymorphism (MS-AFLP) mysid shrimp DNA can be assessed for patterns of methylation that are potentially associated with microplastics exposure. Individuals were dosed with 5 micrometer fluorescent microplastics and compared for differential methylation expression. The experimental groups are compared to a control group sampled before any experiments occured, and to groups that were not dosed, but treated equally in procedure. As part of the experiment, microplastics were delivered with a gradual increase in concentration to determine if methylation is occurring at different rates with different lengths of exposure and different concentrations.

30-5 PROVENCHER, C; CHAN, JC; SPILLANE, J; PLACHETZKI, DC*; University of New Hampshire; *david.plachetzki@unh.edu*

Focusing in on the origin of opsins and phototransduction

All modes of animal vision depend on opsin proteins of the G protein coupled receptor (GPCR) class. Opsins are present across animals and cnidarian opsins were first described more than a decade ago. After much progress, fundamental questions stemming from the paucity of opsin data representing the major lineages of Cnidaria persist. Recent phylogenomic analyses have clarified cnidarian relationships and provide a comprehensive set of genome-scale datasets that could ameliorate these issues. Here we describe a new bioinformatic approach called Phylogenetic Focusing that progressively circumscribes complete orthologous clades of interest within their larger gene families. We applied phylogenetic focusing to a selection of 60 cnidarian and 25 outgroup genome-scale datasets and find that the GPCR neighborhood within which opsins reside is populated by several, previously undescribed clades of non-bilaterian GPCRs including major radiations in sponges, ctenophores and cnidarians. This finding challenges the view that melatonin receptors are the close evolutionary sister to opsins and highlights a hidden diversity of GPCRs in the close vicinity of opsins. In addition, cnidarians are inferred to have inherited the full complement of opsin types but have lost several of them in a lineage specific manner, leaving anthozoans as the cnidarian clade that best represents the ancestral cnidarian opsin palate. Finally, the rate of opsin gene duplication and loss is significantly higher for many cnidarian taxa as compared to other animal lineages, indicating a tumultuous evolutionary history for cnidarian opsins.

129-2 PROVINI, P*; BRUNET, A; VAN WASSENBERGH, S; Muséum National d'Histoire Naturelle; *pauline.provini@mnhn.fr*

Intra-Oral Hydrodynamics of Suction Feeding in Fishes

To capture prey by suction, fishes generate a high velocity flow of water entering the mouth and exiting at the back of the head. Although the hydrodynamics associated with suction feeding is prominent to catch food successfully, difficult optical access to the buccal cavity makes it still poorly understood. Here, we used the technique of X-ray particle tracking, which we optimized to quantify intra-oral flow dynamics in three dimensions. This method requires the use of at least two X-ray sources and radio-opaque particles of densities close to that of the fluid medium. We specifically designed small, approximately neutrally buoyant radio-opaque particles composed of 1.4 mm diameter polystyrene foam spheres with an insert of an X-ray absorbing metal marker. Two individuals of Carp (*Cyprinus carpio*) were implanted with 0.35 mm diameter radio-opaque markers on the upper jaw, lower jaw, hyoid, suspensorium, branchial arches, opercula, skull and pectoral girdle, in order to link the quantified water motions with skeletal kinematics, using XROMM methods. Fishes were filmed during capturing and intra-oral manipulation of food and surrounding flow tracer particles. This analysis allowed us to obtain a more complete view on the 3D kinematics of both the animal‘s cranial system and intra-oral water during feeding.

25-4 PRUETT, JE*; FARGEVIEILLE, A; WARNER, DA; Auburn University; *jep0057@auburn.edu*

Maternal nest choice and the effects of nest microclimate on egg survival in the brown anole

Maternal nest choice plays an important role in the development of embryos in oviparous species. Embryos are subject to the conditions chosen by the mother, and in many species, display a high degree of plasticity in response to developmental environment. The sensitivity of these embryos to their surroundings places a great amount importance on the conditions females select. Nesting behavior varies widely across species with reproductive strategies. The brown anole (*Anolis sagrei*), for example, exhibits fixed clutch size, laying one egg every 7-10 days across an extended reproductive season that can last from April to October. Anoles present an interesting system for studying the effects of nest site choice for many reasons. First, anoles have well-documented plastic responses to developmental conditions such as incubation temperature and moisture. Second, the extended nesting season means females are nesting in very different climatic conditions across the season. To quantify maternal nesting behavior and determine effects of developmental conditions on survival in the brown anole, we searched for maternal nest sites using both targeted and randomized searching methods, and we incubated eggs in the field for most of their developmental period. Mothers chose nest sites with higher moisture and lower temperatures relative to what was available at random across the nesting season. However, nesting behavior varied among sampling periods with mothers choosing more shaded sites in the hotter part of the season. This result was paralleled in the egg placement study with survival probability of eggs decreasing with increasing nest temperature.

P2-110 PUJADE BUSQUETA, L*; DEYARMIN, JS; MCCORMLEY, MC; CHAMPAGNE, CD; CROCKER, DE; HOUSER, DS; KHUDYAKOV, JI; Univ. of the Pacific, Stockton, Natl. Marine Mammal Foundation, San Diego, Sonoma State Univ., Rohnert Park; *l_pujadebusqueta@u.pacific.edu*

Development of a Biomarker Panel of Stress in Free-ranging Marine Mammals

Anthropogenic disturbance in marine ecosystems can impact the health and survival of marine mammals. Stress activates the hypothalamic-pituitary-adrenal (HPA) axis, resulting in increased circulating glucocorticoids, which alter expression of target genes such as metabolic enzymes. Prolonged or repeated stress may increase catabolism of nutrient stores and suppress immune and reproductive functions, impacting fitness. Our objective was to develop a biomarker panel of stress that can discriminate between acute and chronic stress states in marine mammals. We previously characterized endocrine and metabolic profiles and identified genes differentially expressed in blubber in response to repeated adrenocorticotropic hormone (ACTH) administration in juvenile northern elephant seals. Upregulated genes included those encoding lipid particle proteins, adipokines, and antioxidant and lipid metabolism enzymes, while downregulated genes included inhibitors of adipogenesis, gluconeogenesis and inflammation. To validate our biomarker panel, we collected blood and blubber samples from elephant seals of varying body condition and baseline stress states. We measured endocrine (cortisol, aldosterone, total T3, reverse T3) and metabolic (triglyceride) markers in blood using immunoassays and colorimetric assays and candidate gene expression in blubber using RT-qPCR. Gene expression levels were significantly correlated with elevated stress hormones, decreased triglycerides and lower body condition index. These markers provide insights into molecular mediators of the stress response and comprise a potential diagnostic panel for differentiating stress states in marine mammals.

P1-256 PULVER, O*; WILCOXEN , TE; SEITZ, J; NUZZO , JT; Millikin University , Illinois Raptor Center, Illinois Raptor Center; *twilcoxen@millikin.edu*

Patterns of Seroprevalence of West Nile Virus in Clinic-Admitted Raptor Species in Central Illinois

West Nile Virus (WNV) is a virus that is commonly found in avian species in the Midwest. WNV commonly follows a bird-mosquito-bird transmission pattern, with birds serving as amplifying hosts. Plasma samples from raptor species that were admitted to a rehabilitation clinic in Central Illinois were analyzed for each immunoglobulin Y (IgY) and immunoglobulin M (IgM) antibodies against WNV using an enzyme-linked immunosorbent assay (ELISA). In all, 270 birds from seven different raptor species were tested for IgY and 175 birds from seven different raptor species were tested for IgM. Data were then analyzed for possible differences in patterns of infection between years, among species, and among other studies. There were significant differences in seroprevalence among species. In addition, when compared to a study in Wisconsin, our study had a much higher prevalence in all species that were tested, which may be a product of a longer active season for vectors in Central Illinois.

27-1 PYLE, TJ*; SIEFFERMAN, L; Appalachian State University; *pylet@appstate.edu*
Influence of animal personality and density on Mycoplasma gallisepticum prevalence in Eastern bluebirds
It has long been known that animal density can influence the likelihood of pathogen transmission, but emerging research suggests that animal personality can also have profound effects on pathogen transmission. Individual animals within populations often exhibit consistent behavioral phenotypes- some are social, show high exploratory behaviors, are aggressive and bold while others avoid social interactions, are less exploratory and tend to be meek and cautious. Because individuals with certain behavioral phenotypes may be more prone to interact socially and transmit pathogens, infectious diseases of wild animals can be powerful models for testing epidemiological hypotheses. We studied box nesting wild Eastern bluebirds (*Silia sialis*) to improve our understanding of the interplay between density and personality on disease dynamics. We tested the hypothesis that breeding density and animal personality interact to influence the risk of infection by *Mycoplasma gallisepticum* (MG). Using an antibody test, we determined whether animals had contracted MG (an infectious avian respiratory disease). We found no evidence that more aggressive birds were found in high densities which allowed for the separation of personality and density on MG prevalence. MG was most prevalent in bluebirds breeding in high densities. Further, among the birds breeding at low densities, those with aggressive phenotypes were more likely to have contracted MG. These data reveal that the influence of animal personality on the likelihood of contracting MG may be context dependent. Increased focus on how wildlife disease dynamics can be impacted by animal personality within ecological contexts may be important for investigating and management of emerging diseases.

P1-76 PYLES, R.A.*; MATHIS, K.A.; STEWART, J.R.; ECAY, T.W.; East Tennessee State University; *pylesr@etsu.edu*
Impact of Eggshell Calcium on Skeletal Development in an Oviparous Snake
The mineralized eggshell of Reptilia was a major innovation in the evolution of the amniotic egg. Maternally deposited calcium serves to strengthen the eggshell and provide a source of nutrients for developing embryos. Embryos of oviparous reptiles extract calcium from eggshells but vary in their dependence on this source. In the corn snake, *Pantherophis guttatus*, embryos obtain most calcium from yolk, but also mobilize calcium from the eggshell. This suggests that acquisition of eggshell calcium may be facultative and that yolk provides sufficient calcium for successful development. We tested the hypothesis that embryonic development is not dependent on eggshell calcium by manipulating calcium availability. The outer calcareous layer of the eggshell was either left intact (control) or peeled off recently oviposited eggs. There was no difference in survivorship or length of incubation between treatments. We measured calcium content of hatchlings and analyzed skeletal development using cleared & stained specimens. Hatchlings from intact eggs contained more calcium and were larger in mass and length than siblings from peeled eggs. There were no observable differences in ossification but hatchlings from intact eggs had longer skulls and vertebrae. Our results indicate that mobilization of eggshell calcium is not a requirement for successful embryonic development of *P. guttatus* but does serve to augment yolk calcium. This pattern would favor embryos with a greater capacity to mobilize calcium from the eggshell by promoting growth and enhancing hatchling fitness.

P2-96 QUIMBY, K*; CREWS, SC; SPAGNA, JC; William Paterson University, California Academy of Sciences; *quimbyk1@student.wpunj.edu*
Compensation for leg-loss in rotating prey-strikes of "flattie" spiders (Araneae: Selenopidae)
Spiders in the family Selenopidae, commonly called "flatties," have been characterized as having the fastest rotational prey strikes of any animal. While previous work developed a model of rotational striking based on intact, eight-legged spiders, here we used this model as a basis to analyze the strikes of flatties missing one or two legs. Flatties (*Karaops sp.*) were collected in Australia and filmed using high-speed digital video cameras attacking fruit fly prey. Using rotational speed as a measure of performance, we found that spiders missing one leg were only marginally slower (13% reduction in speed, $p = 0.054$) than intact individuals (2.13 ± 0.38 deg/ms for seven legs, vs 2.48 ± 0.61 for intact spiders) while those missing two legs were much slower (54% reduction, $p < 0.001$, mean speed 1.15 ± 0.50 deg/ms), though all could successfully grab prey. Analysis of changes in leg use by 7 legged spiders in rotational attacks showed that about half of the spiders that had lost a single rear leg would compensate by shifting the roles of the back two legs- as described by the Yu and Crews (2018) model-"forward" by one leg. Seven-legged individuals that compensated this way maintained rotational speeds averaging 93% of the intact spider speed, while those that adopted some other pattern maintained only 65% of the speed of eight-legged individuals. These findings demonstrate that flattie spiders can (but don't always) compensate for leg-loss by substituting anterior legs for missing rear legs. This provides evidence supporting optimality for the modeled pattern, but the effects of gait changes on prey capture rates and overall fitness remain unknown.

P2-74 QUINLAN, PD*; RAMIREZ, MD; DRESCHER, B; KATZ, PS; Univ. of Massachusetts Amherst; *pquinlan@umass.edu*
Behavioral Characterization of Berghia stephanieae: A Novel Laboratory Species for Neuroethological Research
The simple nervous systems and behaviors of sea slugs such as *Aplysia californica* and *Tritonia diomedea* make them useful animals for neuroethological research. However, these species must be caught in the wild or raised in large aquaculture facilities. Here, we introduce the nudibranch, *Berghia stephanieae*, as an experimental system that is easily bred and raised in the lab. The generation time for *Berghia* is approximately two months, allowing developmental studies to be performed. Furthermore, it is inexpensive to generate hundreds of animals, making it amenable for undergraduate research. We are characterizing behaviors in *Berghia* to develop a foundation for further research on the neural basis of behavior. Several behaviors are easily observed in the lab, including navigation with visual or chemosensory cues and feeding behavior. Spatial vision had not previously been demonstrated in nudibranchs; we found that *Berghia* can navigate toward a black stripe outside of a circular arena. Like *Aplysia, Berghia* exhibits rhythmic head-waving when searching for food. However, unlike either *Aplysia* or *Tritonia, Berghia* can locate food in the absence of water flow in both an open arena and a T-maze. Food localization requires the rhinophores, the olfactory organs. We are combining this behavioral work with transcriptomic and connectomic approaches to study the neural basis of these behaviors.

81-1 QUINN, BL*; XI, SY; HSIEH, ST; Temple University, Harriton High School; *brooke.quinn@temple.edu*

Can learning facilitate perturbation recovery following limb loss in tarantulas?

Some vertebrates and many arthropods can voluntarily lose an appendage (i.e., autotomize) during antagonistic encounters. Yet, how animals alter limb use to accommodate the loss of locomotor limbs is poorly understood. A recent study showed intact wolf spiders using an alternating tetrapod gait, and switching to a more stable alternating tripod gait after autotomy of two limbs. We hypothesized that spiders use learning to expedite autotomy-induced gait changes and will switch gaits more rapidly after a previous limb loss event. We acquired hatchling tarantulas (*Davus pentaloris*) that had never lost limbs prior to our study. We recorded dorsal views at 500 fps (Photron SA-3), first with all limbs intact (control) and then following removal of two limbs from one tetrapod. Upon limb regeneration, we recorded more control trials and then autotomized the same two limbs. We calculated relative limb phases to categorize the spiders' gaits. Autotomy had no significant effect on running speed ($F=1.32$, $p=0.28$) and basic stride kinematics were different from control only following the first autotomy. Duty factor did not change ($F = 1.51$, $p = 0.22$) among all treatments. However, stride length increased ($F = 12.56$, $p < 0.0001$) and stride frequency decreased ($F = 8.00$, $p < 0.0001$) following the first autotomy only. In control trials, the alternating tetrapod gait was used in the majority of the trials (32 of 42). Following limb autotomy, we observed a temporal shift from using the ablated tetrapod gait to the alternating tripod gait; but the rate of this shift did not appear to differ between the autotomy treatments. These results suggest that there are multiple strategies for adapting to limb loss and that learning is not necessarily a critical component of this compensatory process.

P3-186 QUIROGA-ARTIGAS, G*; BRADSHAW, B; GAHAN, J; SANDERS, N; BARREIRA, S; JONES, A; BAXEVANIS, A; FRANK, U; SCHNITZLER, C; Whitney Lab, UF, National University of Ireland, Galway, NHGRI, National Institutes of Health; *gonzalo.artigas@whitney.ufl.edu*

Transcriptomic profiling of head regeneration in the cnidarian Hydractinia

Understanding why a diversity of regenerative potential exists throughout the animal kingdom remains a major question in biology. In our lab we use the colonial hydrozoan *Hydractinia*, which is capable of fully regenerating a feeding polyp's head in about 72 hours. This dramatic process is orchestrated by migratory adult stem cells, known as interstitial cells (or i-cells). Cell proliferation and blastema formation are two essential steps of head regeneration in *Hydractinia*. To analyze the genes involved in this process, we extracted the mRNA of presumptive blastema tissue (upper body column) from feeding polyps whose heads had just been removed as well as blastema tissue at 24 hours after head removal, and we performed RNAseq and differential expression analyses. We found 2438 transcripts differentially expressed in blastema tissue at 24 hours, with 1246 transcripts downregulated and 1192 upregulated compared to control tissue. We chose a subset of these genes, many of which are differentially expressed during head regeneration in *Hydra*, another highly regenerative hydrozoan, and carried out qPCR analysis. The results we obtained validated the RNAseq data and led to the observation that similar gene networks are used in head regeneration among hydrozoans. We are also performing *in situ* hybridization on a number of genes to characterize their spatial expression during homeostasis and regeneration. This study provides an overview of gene expression during head regeneration in *Hydractinia*, and enables present and future comparisons of the gene networks used by different animals throughout regeneration.

P2-59 RACICOT, KJ*; CUNHA, FB; HENRIKSEN, R; WRIGHT, D; IWANIUK, AN; Univ. of Lethbridge, Alberta, Canada, Linköping Univ., Sweden, Linköping Univ., Sweden; *k.racicot@uleth.ca*

Chickens Have Larger Cerebella Than Junglefowl: Implications for the Effects of Domestication on the Brain

Domestication is the process by which wild organisms become adapted for human use. Many phenotypic changes are associated with animal domestication, including decreases in brain and brain region sizes. Although the effects of domestication on the brain have been investigated across a range of species, almost nothing is known about chicken (*Gallus gallus d.*) brains relative to their wild counterpart, the red junglefowl (*G. g. gallus*). Here, we tested for differences between junglefowl and chickens in the anatomy of the cerebellum, a brain region that is typically smaller in domesticates relative to wild populations. We quantified cerebellar anatomy of red junglefowl and white leghorn (WL) chickens with unbiased stereology. Relative to body and brain size, junglefowl have smaller cerebella than WL chickens and other chicken breeds. However, chickens and junglefowl do not have relatively smaller cerebella than other galliform species. WL chickens and junglefowl also differed in the proportional sizes of the granule cell and white matter layers within the cerebellum. Purkinje cell size did not differ between WL chickens and junglefowl, but WL chickens had more Purkinje cells. When compared with other galliform species, both WL chickens and junglefowl had fewer and smaller Purkinje cells relative to cerebellum size. Overall, these results suggest that the cerebellar anatomy of *Gallus* species differ from other galliforms and that the effects of domestication on the chicken brain differ from that of other domesticated species.

136-6 RADER, JA*; HEDRICK, TL; UNC Chapel Hill; *jrader@live.unc.edu*

Aerodynamics, not load, predicts avian wing thickness

The wings of flapping fliers must be strong enough to resist the aerodynamic and inertial loads placed on them while also maintaining an aerodynamically appropriate shape for producing the requisite forces during flapping and gliding flight. The balance of these pressures differs among species with different flight styles and ecologies and wing morphology is expected to vary accordingly. In addition to 2D shape traits, such as aspect ratio, 3D attributes of wing morphology including camber and thickness may also vary significantly among species, and contribute to structural and aerodynamic function. North American raptors (Falconiformes) display a range of flight and hunting styles and vary in body mass by more than an order of magnitude, providing an opportunity to explore how wing morphology scales with body size, how it varies with flight behavior, and what constrains it. We collected 3D shape data from 200 individuals encompassing 19 raptor species, as well as two species of New World vultures (*Coragyps atratus* and *Cathartes aura*) using a laser scanner (NextEngine, Inc.) and analyzed 2D and 3D shape variables from the wing scans using custom programs in MATLAB and R. We hypothesized that if structural stiffness was the paramount pressure, wing thickness should be best predicted by bending load (proportional to mass*wing length). Conversely, if wing thickness is constrained by the aerodynamics of the wing, it should be best predicted by 2D attributes such as wing length and chord. We found that, in phylogenetically corrected and uncorrected models, wing thickness is better predicted by 2D attributes of wing shape (PGLS, r^2=0.97, p<0.001) than by bending load (r^2=0.66, ΔAIC=244.9, p<0.01) or body mass (r^2=0.71, ΔAIC=173.4, p<0.01), suggesting that 3D wing shape, at least in the Falconiformes, is aerodynamically, rather than structurally constrained.

78-7 RAGSDALE, AK; MILLER, K; COLOMBO, RE; MENZE, MA; SCHREY, AW*; University of Otago, Dunedin , Georgia Southern University, Savannah, Eastern Illinois University, Charleston, University of Louisville, Louisville; *aschrey@georgiasouthern.edu*

DNA Methylation is Altered in Bluegill Sunfish, Lepomis macrochirus, as Consequence of Anthropogenic Thermal Stress

Epigenetic mechanisms can change gene expression and phenotypes in response to environmental stress. Power plant-cooling lakes emblemize anthropogenic temperature changes and two lakes in Illinois exhibit characteristics essential to studying temperature induced phenotypic changes. We compared populations of Bluegill sunfish in the power plant-cooling Lake Coffeen which is 2-6 ºC warmer to populations in the nearby ambient Lake Mattoon. Bluegill in the thermally-elevated lake have a shorter lifespan, show a decrease in growth performance, and population structure is skewed towards younger fish. We performed MS-AFLP to determine if DNA methylation differed between fish from the thermally-elevated and ambient lake. We identified significant epigenetic differentiation between specimens from both lakes and we identified five loci with increased, and two loci with decreased DNA methylation among individuals in the thermally-elevated lake compared to the ambient lake. Further, our results show differentiation in the frequency of methylation among sites between lakes, while sites within the thermally challenged lake did not differ. These results suggest that DNA methylation is an important mechanism contributing to the observed phenotypic variation in Bluegill from thermally-elevated lakes compared to ambient lakes. We then used epiRADseq to generate 185,166 fragments to compare broad scale genomic differences in DNA methylation among fish from Lake Coffeen, Lake Mattoon, and Bluegill collected in Puerto Rico, which serve as a geographically disjunct group with higher ambient temperatures. We will compare results between MS-AFLP and epiRADseq.

35-4 RAHMAN, MD/S*; THOMAS, PETER; University of Texas Rio Grande Valley, Brownsville, TX, University of Texas Marine Science Institute, Port Aransas, TX; *md.rahman@utrgv.edu*

Effects of environmental hypoxia on reproductive endocrine functions, molecular and epigenetic signals in Atlantic croaker

Knowledge of the effects of environmental exposure to hypoxia on critical physiological functions is essential for accurate predictions of its chronic impacts on aquatic organism. Marked disruption of reproductive and endocrine functions was observed in Atlantic croaker collected from the hypoxic region in the northern Gulf of Mexico. Recent research has shown that growth and its physiological upregulation is also impaired in hypoxia-exposed marine fish. Expression of IGFBP, a growth inhibitory protein, and HIF-1alpha, an oxygen-sensitive transcription factor, were upregulated in croaker tissues collected from hypoxic environments. Preliminary field and laboratory studies indicate that hypoxia exposure also causes epigenetic modifications, including increases in global DNA methylation in croaker. Epigenetic modifications can be passed to offspring and persist in future generations no longer exposed to the environmental stressor. Collectively, the results indicate that environmental hypoxia exposure disrupts major physiological functions in a marine teleost species critical for maintenance of fish populations.

100-4 RAMASWAMY, S.S; SANE, S.P.*; National Centre for Biological Sciences, TIFR; *sane@ncbs.res.in*

The role of water and pheromones in mound-building behavior in termites

Mound-building termites construct build tall structures using the soil available from their surroundings. These mounds house their entire subterranean colony, which consists of a queen, who generates major and minor workers, soldiers and reproductive alates that take wing when the ambient humidity conditions are favourable. In addition to the termite colony, termites also farm a fungus strain that exclusively grows within the mound and helps the termites digest wood. When building or repairing mounds, large numbers of termites are recruited to the building site where they then perform repetitive actions which involves regurgitating soil, rolling it into small boluses that are then used as the building bricks. For the clay to stick it must contain water. Because this activity occurs throughout the year ranging from heavily rainy monsoons to very dry summers, we studied how water content influenced building rates. We conducted a series of experiments which reveal that specific water content in the soil enables termites to maintain optimal building rates. This activity is collective, and also requires chemically mediated (perhaps through pheromones) recruitment of termites to ensure sustained building activity. We also show that this chemical is quite stable to temperature increases in excess of what termites would experience in their natural habitat.

P2-53 RAMIREZ, S*; MELTON, RL; FUSE, M; RAMIREZ, sergio; San Francisco State University; *sramire6@mail.sfsu.edu*

Protein synthesis is required for long-term nociceptive sensitization in the hornworm, Manduca sexta

Over 100 million Americans nationwide experience chronic pain resulting in over $600 billion spent on treatment each year. Due to this, it is vital to understand the pain signaling pathway and the inhibition of downstream signaling mechanisms with the aid of the insect model, Manduca sexta. M. sexta have been shown to undergo central sensitization after noxious stimuli, such as a pinch or extreme cold, both in vivo and in vitro. These noxious stimuli induce a state of sensitivity, which reduce the force required to elicit a strike, which can last up to 19 hr in M. sexta. In order to determine the role of protein synthesis in the maintenance of nociceptive sensitization in M. sexta, Cycloheximide, a protein synthesis inhibitor, was injected into M. sexta, and nociceptive sensitization was assessed with an in vivo assay. Animals injected with Cycloheximide no longer showed sensitization within 3 hr and up to 19 hr after a noxious pinch, while there was no effect 1 hr after the pinch. Control pinched animals remained sensitized at the 19 hr time frame. Between the first and third hour the greatest changes of sensitization were seen, suggesting full inhibition of protein synthesis taking a minimum of 3 hours post injection. This suggests that protein synthesis is not needed to induce sensitization but is required to maintain this heightened state. Exploration of these mechanisms will help better understand aspects of chronic pain signaling in humans, to aid in the synthesis of improved pharmaceuticals.

P2-63 RAMIREZ, MD*; DWYER, J; BERGAN, JF; KATZ, PS; Univ. of Massachusetts Amherst; *mdramirez@umass.edu*

Creation of a standardized reference brain atlas for the nudibranch, Berghia stephanieae

Identifying neuronal types within brains is key to understanding their roles in circuits underlying behavior. The brains of gastropod molluscs, such as the nudibranch *Berghia stephanieae*, contain a modest number of neurons (~7,000), many potentially identifiable by anatomical and neurochemical phenotypes. These traits make classifying every neuronal type feasible. Despite this, only a handful of neurons in gastropods have been identified and named. Gastropod brain development is determinate, but the precise soma locations and branching patterns are stochastic. This makes comparing brains and neurons across individual animals challenging. To address this obstacle, we are creating a standardized reference brain atlas for *Berghia*. We used CLARITY to clear whole animals and imaged them with lightsheet microscopy, leaving the brain in its true anatomical position. Clearing with CLARITY took ~2 weeks with minimal hands-on time. A lightsheet microscope easily accommodates the small slugs, allowing entire animal to be imaged in only a few minutes. We are currently aligning and averaging multiple 3D autofluorescent brain images together to create the reference brain. The CLARITY protocol preserves proteins in place, allowing us to use immunohistochemistry (IHC) sequentially on the same sample to start identifying neuronal types. So far we have labeled serotonin, small cardioactive peptide, and FMRFamide. Many neurons expressed only one of the 3 neurotransmitters we labeled with IHC. We found cells that are likely homologous to previously identified neurons in other nudibranchs based on position and labelling. Once the reference brain is completed, we will continue to add IHC and *in situ* hybridization labeling for other markers to identify all neuronal types in the *Berghia* brain. This protocol is likely applicable to other smaller invertebrates to create reference brain atlases.

27-6 RAMSAY, CR*; ROHR, JR; University of South Florida; *chloeramsay@mail.usf.edu*

Order of Infection Impacts Disease Progression in Frogs

Co-infecting pathogens interact with each other and their environment, the host, but foundational concepts from community ecology, such as priority effects, have rarely been used to understand co-infection. Here, we tested how the timing of infection with common and deadly amphibian pathogens impacts pathogen load, host growth, and survival; hypothesizing that larger time lags between pathogen exposures will lead to a greater competitive advantage for the initial pathogen. We infected post-metamorphic Cuban tree frogs (*Osteopilus septentrionalis*) with Ranavirus, the fungus *Batrachochytrium dendrobatidis* (Bd), a nematode *Aplectana hamatospicula*, or two of the three pathogens either sequentially or simultaneously. Prior infection with other pathogens altered Ranaviral and *A. hamatospicula* pathogen loads, significantly increasing Ranaviral pathogen loads for co-infected versus singly infected hosts and changing *A. hamatospicula* pathogen load depending on co-infecting pathogen. Time since previous infection was important for Bd infected hosts, but whether a longer time since infection increased or decreased loads depended on the co-infecting pathogen. Finally, infections with Bd and Ranavirus decreased host growth and survival. These results suggest that the order of infection can impact disease progression, and that some secondary infections can exacerbate consequences for hosts while others can ameliorate them.

101-1 RAMSEY, AJ*; MCCAULEY, DE; MANDEL, JR; University of Memphis, Vanderbilt University; *adam.ramsey@memphis.edu*

Patterns of cytonuclear linkage disequilibrium differ between heteroplasmic and homoplasmic individuals of wild carrot, Daucus carota (Apiaceae), a gynodioecious plant species

Cytonuclear linkage disequilibrium (LD) is the non-random association of alleles between nuclear and cytoplasmic genomes (ptDNA or mtDNA). Patterns of cytonuclear LD can indicate admixture of divergent populations, cytonuclear selection, non-traditional organellar inheritance, or the occurrence of more than one type of mtDNA or ptDNA within an individual (heteroplasmy). Gynodioecious plant species are known to exhibit biparental inheritance of organelles, creating heteroplasmy. We used the gynodioecious plant species, *Daucus carota*, or wild carrot, to investigate cytonuclear LD. We genotyped 265 individuals from two North American regions, 136 from the Olympic Peninsula, Washington State and 129 from Nantucket Island, Massachusetts. We used 15 nuclear microsatellites, one SNP and one insertion-deletion (indel) located in the mtDNA, and one indel located in the ptDNA to calculate nuclear-nuclear LD, cytonuclear LD, and LD between each pair of organellar loci. We were further able to identify over 100 individuals heteroplasmic for one of the mitochondrial SNPs and over 30 individuals heteroplasmic for the plastid indel. Thus, we were able to calculate the same sets of cytonuclear LD values for individuals that are heteroplasmic and homoplasmic (non-heteroplasmic) for the mitochondrial SNP and plastid indel. When considering heteroplasmy or homoplasmy as the cytotype, no non-random associations were found, and LD values were low. However, when considering the SNP or indel variant as the cytotype, differences were found in the LD values between heteroplasmic and homoplasmic groups. In particular, the range of LD values increased when found in the heteroplasmic state.

101-7 RAND, DM*; MOSSMAN, JA; Brown University; *David_Rand@brown.edu*

Mitonuclear epistasis, genotype-by-environment interactions and personalized genomics of complex traits in Drosophila

Mitochondrial function requires the coordinated expression of dozens of gene products from the mitochondrial genome and hundreds from the nuclear genomes. The systems that emerge from these interactions convert the food we eat and the oxygen we breathe into energy for life, while regulating a wide range of other cellular processes. These facts beg the question of whether the gene-by-gene interactions (GxG) that enable mitochondrial function are distinct from the gene-by-environment interactions (GxE) that fuel mitochondrial activity. We examine this question using a Drosophila model of mitonuclear interactions in which experimental combinations of mtDNA and nuclear chromosomes generate pairs of mitonuclear genotypes to test for epistatic interactions (GxG). These mitonuclear genotypes are then exposed to altered dietary or oxygen environments to test for GxE interactions. We use development time to assess dietary effects, and genome wide RNAseq analyses to assess hypoxic effects on transcription, which can be partitioned in to mito, nuclear, and environmental (GxGxE) contributions to these complex traits. We find that mitonuclear epistasis is universal, and that dietary and hypoxic treatments alter the epistatic interactions. We further show that the transcriptional response to alternative mitonuclear interactions has significant overlap with the transcriptional response to alternative oxygen environments. Gene coexpression analyses suggest that these shared genes are more central in networks of gene interactions, implying some functional overlap between epistasis and genotype by environment interactions. These results are discussed in the context of evolutionary fitness, the genetic basis of complex traits, and the challenge of mapping genotypes in to phenotypes.

23-3 RANGE , RC; Auburn University; *range@auburn.edu*
Evolution of Anterior-Posterior Axis Specification and Patterning: Insights from the Sea Urchin Embryo
The early specification and patterning of cell fates along the primary body axis of many metazoan embryos relies on a gradient of Wnt signaling. In most embryos this patterning mechanism depends primarily on high levels of localized canonical Wnt/&beta-catenin signaling around one pole of this embryonic axis, which will form endoderm/endomesoderm, and localized Wnt signaling antagonists around the opposite pole that typically aid in specifying the ectodermal and neuroectodermal territories. We have recently shown for the first time in any embryo that the deuterostome sea urchin integrates information from three different Wnt signaling branches (Wnt/&beta-catenin, Wnt/JNK, and Wnt/PKC pathways) to specify and pattern early regulatory states along the embryonic anterior-posterior axis. Here, we present new functional evidence suggesting that the three Wnt branches interact through several extracellular Wnt signaling modulators (Wnt1, Wnt8, Wnt16, sFRP1/5, sFRP1, Dkk1, Dkk3 and Wif-1) and receptors (Fzl5/8 and Fzl1/2/7). Our data also suggest these Wnt branches also interact through intracellular transduction molecules (e.g. PKC, NFAT, and ATF2) and the transcriptional gene regulatory networks they activate. These data represent the first steps in our strategy to use a combination of high-throughput genome-wide assays, molecular manipulations, and gene regulatory network analysis to produce a systems-level model of how this Wnt signaling network governs anterior-posterior axis specification in the sea urchin embryo. Importantly, evidence from functional and expression studies in other embryos strongly suggests that aspects of this fundamental developmental mechanism are conserved in deuterostome embryos.

89-2 RANK, NE*; MARDULYN, PM; HEIDL, S; ROBERTS, KT; ZHANG, B; DAHLHOFF, EP; Sonoma State University, University of Brussels, Santa Clara University; *rank@sonoma.edu*
Mitonuclear interactions influence performance and reproductive characters in a montane leaf beetle
Mitonuclear interactions are implicated in many evolutionary processes. Evidence suggests that they reduce fitness in individuals with mismatched mitochondrial and nuclear genomes, but this is poorly understood in natural populations. We investigated mitonuclear interactions in the beetle *Chrysomela aeneicollis*. Populations live along altitudinal transects that impose temperature and oxygen stress. We analyzed variation along a 75 km latitudinal transect and found that the nuclear metabolic enzyme locus PGI and mitochondrial protein-coding COII diverge more than other genes. We measured reproduction and development of BC beetles in nature and performance and infection level by *Wolbachia* bacteria in the laboratory. We found that females homozygous for the PGI genotype common in northern populations laid more eggs if they had the mitochondrial haplotype common in the north, while females homozygous for the PGI allele most common in south laid more eggs if they had the southern haplotype. Larval development showed a similar pattern. In the laboratory, adults with matched genotypes ran faster and had higher mitochondrial enzyme activities than those with mismatched genotypes, especially after heat exposure. In contrast, running speed and male mating success showed mismatch at low elevation, suggesting that environmental hypoxia may affect mitonuclear interactions. Finally, we found that *Wolbachia* level is negatively related to recovery from thermal stress exposure, but the pattern depends on mitochondrial and nuclear genotype. Taken together, these data suggest that mitonuclear interactions significantly alter performance and fitness in beetles living along natural thermal and oxygen gradients.

7-3 RAO, C*; LIU, H; Graduate School of Engineering, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba 263-8522, Japan; *raochen@chiba-u.jp*
Aeroacoustic Noise Suppression and Aerodynamic Robustness in Owl-inspired Leading-edge Serrations
Owls are a master to achieve silent flight in gliding and flapping flights under natural turbulent environments owing to their unique wing morphologies, normally characterized by leading-edge serrations, trailing-edge fringes and velvet-like surfaces. How these morphological features affect aerodynamic force production and aeroacoustic noise suppression is of significance for aerodynamic / aeroacoustic control in biomimetic designs of owl-inspired adaptations for various fluid machineries. In this study, we address a large-eddy simulation-based study of owl-inspired single feather wing models with and without leading-edge serrations over a broad range of angles of attack (AoAs) from 0&deg to 20&deg. Our results show that leading-edge serrations can passively control the laminar-turbulent transition over the upper wing surface, and hence stabilize the suction flow. We also find that there exists a tradeoff between force production and turbulent flow control (i.e. aeroacoustic control): poor at lower AoAs but capable of achieving equivalent aerodynamic performance at higher AoAs > 15&deg compared to the clean model. Furthermore, through mimicking wind-gusts under a longitudinal fluctuation in free-stream inflow and a lateral fluctuation in pitch angle, it is revealed that the serration-based passive flow control mechanisms and the tradeoff hold independently to the wind-gust environments, demonstrating the aerodynamic robustness associated with the leading-edge serrations.

30-2 RASHID, SB*; TASSIA, MG; HALANYCH, KM; MOSS, AG; Auburn University; *sbr0012@auburn.edu*
Matrix Metalloproteinase Gene Evolution in Ctenophora
Matrix Metalloproteinases (MMPs) are conserved zinc-dependent endopeptidases found across all kingdoms of life. They are members of a diverse protein family characterized by their catalytic domain, Metzincin, and are divided into subfamilies based on domain architecture and functional properties. Other major functional domains found in MMPs are the N-terminus propepetide domain which plays a regulatory role and the hemopexin domain. MMPs play roles in tissue remodeling events, such as wound repair and regeneration, and activate other proteins through proteolytic activity, namely signaling pathways regulating immunity. This class of metalloproteinases has been widely studied in vertebrate model systems but less so in early diverging metazoans that lack "complex" extracellular matrix structures. Thus, MMP's ancestral role in metazoans has yet to be determined. Ctenophores are planktonic, marine invertebrates which recent molecular studies have placed as the earliest diverging extant group of animals. Furthermore, ctenophores have been shown to exhibit rapid wound repair and regenerative properties suggesting involvement of MMPs. In this study, we analyze transcriptomic and genomic data through bioinformatics pipelines to reveal the presence of putative MMPs amongst ctenophore and other non-bilaterian taxa. Primary putative homologs were filtered through a series of inclusion criteria including size and domain presence. Each of the MMP amino acid sequences include: a highly conserved cysteine switch motif in the N-terminus indicating the presence of the propeptide domain, a zinc-dependent catalytic domain, and the signature hemopexin. Phylogenetic relationships amongst MMP homologs were inferred through the construction of gene trees.

13-2 RAUSCHER, MJ*; BI, CX; FOX, JL; Case Western Reserve University; *mjr67@case.edu*

Imposed Haltere Oscillations Influence Head and Wing Movements of Tethered Flying Drosophila

Like other flies, fruit flies (*Drosophila melanogaster*) possess a set of modified hind wings called halteres that beat in time with the forewings and act as an inertial sensory system. These modulate fast reflexes stabilizing the head and wings of these insects against unexpected movements, mediated by direct projections of haltere mechanosensory neurons to neck and wing-steering motoneurons. While many aspects of these circuits have been described in rigorous electrophysiological studies, it remains unresolved how haltere afferents encode inertial information and what aspects of haltere mechanosensation are ultimately involved in behavior. Here, we modulate aspects of haltere kinematics and observe behavior in an effort to address these questions. Adult *Drosophila* were tethered to rigid pins and suspended in an insect flight arena, with which the fly was shown either a uniform visual background stimulus or a periodic grating stimulus designed to elicit an optomotor steering response in the head and wings. Concurrent with this visual stimulation, a dorso-ventral movement of one of the halteres was induced via a pair of electromagnets, acting on an iron filing glued to the haltere bulb. Under every visual context, the imposed haltere movements followed the magnetic stimulation frequency with close fidelity, and were accompanied by an identifiable jitter in power spectral density estimates of the head yaw and wing leading edge angle timeseries. In the case of the visual motion stimulus, this jitter appeared to be superimposed on the visual system response, and did not prevent the flies from showing normal optomotor head and wing responses. These findings lay the groundwork for an estimation of the "transfer function" connecting haltere mechanosensation with its downstream targets during particular behavioral contexts.

P2-191 REARDON, KM*; HUSAK, JF; Univ of St Thomas; *rear9362@stthomas.edu*

Increasing mitochondria in lizards raises metabolic rates, but does not enhance endurance

Acquired resources must be allocated to a combination of reproductive output, as well as traits that enhance survival. Whole-organism performance traits are key for survival, but they are also energetically expensive. Previous work with green anoles showed that aerobic exercise (endurance training) forces allocation of resources to enhanced performance at the cost of current reproduction and immunocompetence. In general, aerobic exercise elicits the same response from all vertebrates, both mammalian and non-mammalian, which is an increase in hematocrit and heart size, as well as metabolic changes. In mammals, gene expression is often dramatically altered, and can be done so to increase mitochondria biogenesis for more ATP production, helping with sustained muscle contraction. However, it is unknown if non-mammals use these same molecular pathways to increase aerobic performance. In our study, we experimentally manipulated 48 male green anole lizards that were split among four treatment groups, with endurance training and a supplement as the two balanced factors. The supplement, pyrroloquinoline quinone (PQQ), stimulates the expression of PGC-1a, which in-turn enhances mitochondria biogenesis. We expected PQQ to increase mitochondria densities in muscles and enhance aerobic performance. We recorded time for each lizard to reach exhaustion, both before and after the treatments. We found that training increased endurance, but supplemented lizards did not have further increased endurance. Training alone decreased standard metabolic rates (SMR), but supplemented lizards had significantly increased SMR, suggesting a higher number of mitochondria. Our results suggest that enhanced endurance due to endurance training is likely not due to increased mitochondrial numbers, but instead mitochondrial efficiency.

P2-272 REDAK, CA*; HALANYCH, KM; Auburn University; *czr0057@auburn.edu*

Mitochondrial genome of Parborlasia corrugatus (Nemertea: Lineidae)

Parborlasia corrugatus is a large dioecious, broadcast spawning heteronemertean found in marine systems at higher southern latitudes from the intertidal to 3950 m in depth. Like other nemerteans, *P. corrugatus* has limited external morphology but can display a range of color variation. Additionally, there are at least two populations of *P. corrugatus* with one on the Antarctic continental shelf and one on the South American shelf. Despite having pelagic larvae, these populations have been reproductively isolated by temperature differences created by the Antarctic Polar Front, an open-ocean barrier to gene flow. Within the 15,499 bp mitochondrial genome, we recovered 13 protein coding genes as well as two rRNA and 22 tRNA. The order of tRNA genes have been relatively conserved across nemertean mitogenomes, except for one inversion of tRNAL1 between tRNAL2 when compared to other heteronemertean taxa. The GC% was 35.9% across the genome. Phylogenetic analyses yielded a topology consist with the current understanding of heteronemertean relationships, however, interestingly, *P. corrugatus* exhibited a long branch in our analysis.

36-6 REED, KA*; BLEAU, JM; MUNDEN, TMN; LEE, SG; PARK, HK; COVI, JA; Univ. of North Carolina at Wilmington, Korean Polar Research Institute, Univ. of North Carolina Wilmington; *kar7752@uncw.edu*

Keep calm and sleep on: how to survive as a zooplankton in an Antarctic freshwater lake

Antarctic zooplankton in freshwater lakes produce embryos capable of extended periods of dormancy when conditions are inhospitable for active life-stages. In light of this life history strategy, it is surprising that this study is the first extensive analysis of overwintering strategies, dormancy, and post-dormancy development in a freshwater Antarctic zooplankton. In the present study, post-dormancy development of embryos of *Boeckella poppei* was characterized using light and electron microscopy. The resulting developmental profile was used to assess the effects of anoxia and sub-zero temperatures on subsequent development and hatching success. Embryos of *B. poppei* survived incubation in native sediment at -12°C, but survivorship decreased at -24°C and no successful hatching occurred from embryos incubated at -80°C. In addition to sub-zero temperatures, embryos may face anoxic conditions in Antarctic lakes. The present study demonstrates that embryos continue to develop under severely hypoxic conditions, but can survive anoxic conditions for at least 90 days in a dormant state. To investigate the underlying mechanisms of dormancy and post-dormancy development, ^{31}P-NMR was used to examine intracellular pH and phosphate containing compounds during resurrection from dormancy. Preliminary data demonstrates the existence of shifts in intracellular pH and phosphate containing compounds during the first 48 hours of post-dormancy development. This study establishes the foundation for research on the susceptibility of Antarctic freshwater zooplankton to climate change and anthropogenic influence.

P1-29 REGAN, MC*; GIBB, AC; Wake Forest Univ., Winston Salem, Northern Arizona Univ., Flagstaff; *regamc13@wfu.edu*
Comparison of resistance to tearing in the skin of two flatfishes of the Pacific Northwest
Fishes use skin as their first line of defense against predation or hazards in their habitat, and scales have evolved to armor the skin against potential dangers. Flatfishes are a particularly interesting group in which to examine resistance to tearing, because they rest on the substrate with their "blind" (eyeless) side in direct contract with the substrate. We examined the ability of the skin of two flatfishes, *Platichthys stellatus* (n=6) and *Isopsetta isolepis* (n=6), with two different scale types, tuberculate and ctenoid, to resist tearing. The tuberculate scales of *P. stellatus* are rigid, protruding scales that are sparsely distributed, while the ctenoid scales of *I. isolepis* are overlapping thin scales that cover the entire body. We hypothesized that scale type may affect how the skin resists tearing. Squares of skin were taken from each side (blind or eyed) of the specimen and torn in two different directions (along the dorso-ventral or anterior-posterior axis). Work and extension were measured for each trial and compared across side, species, axis, and organism size. Overall, the species differed ($p < 0.001$) in work required to tear the skin; however, size of the individual also had an effect on work ($p < 0.01$). Because *Platichthys* specimens tended to be larger than *Isopsetta*, the work required to tear a skin sample may be confounded by organism size. The extension of the skin during tearing varied based on the direction the skin was torn ($p < 0.05$); the skin extended more when torn along the anterior-posterior axis vs. the dorso-ventral axis. Ultimately, observations of how scale type influences resistance could yield insights into animal-environment interactions and generate bio-inspired materials for human use.

P1-91 REHFELDT, E*; PATEL, S; HIATT, DJ; KARJASEVIC, A; MCCUE, MD; HATLE, JD; Univ. of North Florida, Sable Systems International; *jhatle@unf.edu*
Effects of dietary restriction on the organismal oxidation of leucine in female grasshoppers
Dietary restriction (energy deficit diet without malnutrition; DR) extends the lifespan of a wide range of animals. Recent studies show that restriction of protein is vital to this extension. Lifespan extension is also achieved through RNAi knockdown of the Target of Rapamycin pathway (a cellular growth pathway; TOR). The TOR pathway is potently stimulated by leucine, which may contribute to the life-shortening effects of a protein-rich diet. Given the energy deficit upon DR, we hypothesize that DR extends lifespan in part through enhanced oxidation of leucine (which would render leucine unable to activate TOR). We predict that female Lubber grasshoppers on DR would oxidize dietary leucine at higher rates than grasshoppers fed *ad libitum*. In past work, leucine oxidation has been observed to increase significantly in some trials and non-significantly in others, with high variability across individuals. In this experiment, grasshoppers (total n=28) each were fed either *ad libitum* or DR for ~40 days, then measured for leucine oxidation (trial 1). These same lubbers were then switched to the other feeding level (*ad libitum* to DR; DR to *ad libitum*) for an additional ~40 days before a second leucine oxidation measurement (trial 2). Oxidation rates did not differ in trial 1, but in trial 2 leucine oxidation rates were higher from 4-8 hr after tracer ingestion (all $P<0.05$; 90-187% increases). These results suggest that leucine can be oxidized at higher rates in lubber grasshoppers upon DR. High variation exists but is not due to individual differences. Overall our results are consistent with previous work in the lab: leucine oxidation can be higher upon DR, but it is not consistently higher.

P1-23 REHOREK, SJ*; STIMMELMAYR, R; GEORGE, JC; SUYDAM, R; MCBURNEY, DM; THEWISSEN, JGM; Slippery Rock University, Slippery Rock, University of Alaska, Fairbanks, North Slope Borough, Barrow, Slippery Rock University, NEOMED, Rootstown; *susan.rehorek@sru.edu*
Role of Desmosomes in the Annual Molting of the External Acoustic Meatus Lining of the Bowhead Whale (Balaena mysticetus): A Preliminary Study.
The external acoustic meatus (EAM) of most baleen whales has no functional connection to the external environment. As a result, as whales age debris accumulates annually in the lumen, in the form of a lamellated ear plug, which have been used to age whales. Most analyses of the ear plug have either been anatomical (counting the layers) or biochemical (determining fat content). Recently it was shown in bowhead whales that the ear plug is formed by an annual molting of the EAM lining. The molting process proceeds with the entire epithelium being torn, at the level of the stratum basale, from the underlying dermis during the spring migration (May). Epithelial regeneration is mostly completed by the fall migration (October). Thus the epithelium remains intact for 6-7 months before it is torn off the following spring. Desmosomes are commonly found in skin, and are a diagnostic feature for maintaining strong cell adhesions. Desmosomes are held together intercellulary by desmoglein and desmocollin proteins, both of which are necessary for desmosomal adhesion. Several paraffin sections of EAM lining of both spring and fall bowhead whale were immunohistochemically examined for the presence of desmoglein and desmocollin. The results revealed near ubiquitous presence of desmoglein (both seasons) and desmocollin (fall), but absence of desmocollin in the stratum basal of the spring specimens. A similar absence of desmocollin has been described in several pathological conditions (e.g. dermatitis, hereditary tissue-fragility disorders), but its role in epithelial injury is not well understood.

28-5 REICH, HG*; RODRIGUEZ, IB; LAJEUNESSE, TC; HO, TY; Penn State University, Academia Sinica, Taiwan; *hgreich16@gmail.com*
Iron limits coral symbionts' survival to heat stress
Trace metals are critical to the persistence of micro-algae (e.g. phytoplankton). Mutualistic endosymbionts, Symbiodiniaceae, deliver and receive nutrients from their reef-building hosts, stony corals. Linking the connection between macro (carbon, nitrogen, phosphorus) and micro-nutrient (trace) quotas in relation to energy cycling between host and symbiont is pertinent to understanding the holobiont's ability to withstand stress events. It is hypothesized that exposure to increased iron availability (and subsequent iron sequestration) may enhance the organism's ability to maintain homeostasis during stress events. To test this hypothesis, *Breviolum spp.* (formerly *Symbiodinium* clade B) cultures were exposed to a full-factorial set of temperatures and iron concentrations. During exponential growth, cultures were sampled for nutrient content (trace metals and major nutrients), chlorophyll, pigments, and photosynthetic physiology to evaluate *Breviolum spp.* condition. Preliminary results indicate that heat stress halts growth and photosynthesis at cultures exposed to low iron concentrations whereas counterparts at higher iron concentrations are able to persist. By combining a broad suite of physiological approaches, we have created the baseline for a *Breviolum spp.* iron stress index to assess the compounding effects of iron limitation and heat stress on the stability of coral-algal symbioses.

P1-144 REICHARD, DG*; BRUSH, JJ; SORRICK, MC; ANGELO, CM; SCHULTZ, EM; Ohio Wesleyan University, Kenyon College; *dgreicha@owu.edu*

Aggressive behavior and signaling in two species of North American wrens

Aggressive behavior and signaling are critical components of territoriality that have a direct effect on an individual's fitness. The selective factors shaping aggression are complex and can lead to divergence among populations and closely related species. We compared aggressive behavior and signaling in two, closely related songbirds, Carolina wrens (*Thryothorus ludovicianus*) and house wrens (*Troglodytes aedon*). Both species breed in North America, but they exhibit distinct life histories. Carolina wrens are sedentary and maintain year round territories while house wrens at our study site are migratory and only maintain seasonal breeding territories. To elicit aggression, we conducted simulated territorial intrusions consisting of five minutes of conspecific song playback without a visual stimulus. We found that male house wrens are significantly more active and sing significantly more broadcast songs than Carolina wrens in response to a simulated intruder. House wrens also maintained a high song output after the playback ended and remained in closer proximity to the speaker. Collectively, these results indicate two distinct aggressive responses that may be explained by the social conditions and life histories of both species. House wrens occur at substantially higher densities and experience frequent intrusions while Carolina wrens occur at low densities on stable, year round territories. As a result, house wrens may benefit from signaling broadly with song to many potential rivals and actively searching during an intrusion while Carolina wrens limit their long-range signaling and instead focus on locating and expelling the lone intruder. However, more data are needed to adequately test these hypotheses.

P2-133 REILLY, ME*; ZARDUS, JD; College of Charleston, SC, The Citadel, Charleston, SC; *reillyme@g.cofc.edu*

Impact of Salinity on Larval Survival and Settlement in the Commensal Barnacle Chelonibia testudinaria

Chelonibia testudinaria is an epibiotic acorn barnacle that attaches to sea turtles, manatees, and crabs. Much is unknown about the mechanisms by which this epibiont finds a host during the planktonic larval stage. This study identified the salinity tolerance of *C. testudinaria* larvae in order to understand in what water masses they are likely to occur and be able to settle on a host. Egg masses were collected from adult barnacles growing on horseshoe crabs and sea turtles. Larvae were reared in filtered seawater at 20 or 30 ppt salinity until they reached the cyprid stage and then groups of cyprids from the same cohort were transferred into beakers with salinities at 10, 15, 20, 25, and 30 ppt respectively. After 72 hours all cyprids were counted and classified as alive, settled, metamorphosed, or dead. Percent mortality and percent settlement were calculated based on total larvae per beaker. Mortality ranged from 2-100% and settlement ranged from 0-89%. Mortality was significantly reduced in the 10 ppt salinity treatment ($P < 0.01$). Settlement (i.e., the sum of both settled and metamorphosed larvae) was significantly reduced in the 10 ppt salinity treatment ($P < 0.01$) but had greater variability between trials than mortality rates.

106-5 REINKE, B*; CAYUELA, H; HOEKSTRA, L; JANZEN, F; BRONIKOWSKI, A; MILLER, D; Pennsylvania State University, Université Laval, Iowa State University, Iowa State University; *bxr389@psu.edu*

Comparing ectotherm senescence using a hierarchical model

An age-dependent decline in survival, called senescence, is a ubiquitous trait in animals. Due to their reduced metabolism, specialized adaptations, and extended longevity, ectotherms such as turtles are thought to have low rates of senescence relative to other animals. Using long-term mark-recapture datasets and a hierarchical senescence model that incorporates growth, we compared the rates of senescence of turtles and snakes for the first time. We found that senescence rates vary both within and among species and we discuss the importance of using long-term data from wild populations to study age-dependent changes in survival. Estimating patterns of senescence is just one practical application of jointly estimating survival and growth; our model can also be used to improve understanding of life-history trade-offs between growth and survival.

P2-285 REITZEL, AM*; WALLER, J; KNIGHTON, L; STROM , O; TRUMAN, AW; Univ. of North Carolina, Charlotte; *areitze2@uncc.edu*

Interactome Complexity and Dynamics Involving Hsp70 Proteins from the Anemone Nematostella vectensis

Heat shock protein 70 (Hsp70) is a nearly universal class of molecular chaperones that are involved in diverse molecular pathways through specific interactions with other proteins. Most organisms have numerous Hsp70s encoded in their genome but it is not understood how similar the client proteins are for these Hsp70 homologs in ambient or heat stress conditions. Here we provide the first description of the homolog-specific diversity of Hsp70 clients for a marine invertebrate species, the cnidarian *Nematostella vectensis*, through heterologous expression in yeast. Using mass spectrometry we determined that three Hsp70s from this sea anemone interact with 100s of proteins. Despite the high sequence similarity of the Hsp70s, less than 50% of identified interacting proteins were common to all three anemone Hsp70s and as many as 18% were unique to an individual Hsp70. The overall enrichment of functions for these interacting proteins was similar for each Hsp70 despite this limited conservation of particular client proteins. Our study provides the first data set defining the potential "interactome" of Hsp70s for a marine species and suggest numerous specific interactions for Hsp70 homologs. Together, these data reveal a rich set of interacting proteins for Hsp70 that may be novel biomarkers to characterize the response of cnidarians to their rapidly changing environments.

49-5 RESH, C. A.*; MAHON, A. R.; Central Michigan University; *carlee.resh@gmail.com*

Improving the Efficiency of DNA Extraction from Samples Collected for Environmental DNA Surveillance

Early detection is paramount to effective management and regulation of rare species in aquatic and marine ecosystems. Successful early detection relies on timely results of species surveillance and monitoring. As a result, approaches have been developed using molecular tools to sample environmental DNA shed from targeted species. This noninvasive approach is cost and time efficient for monitoring species that are threatened, endangered, or recently introduced. Time efficiency from sample collection through data analyses and maintaining sterility to avoid contamination are crucial. However, current protocols require nearly 48 hours to complete, from sample collection through availability of DNA for downstream analyses. Here, we aim to reduce sample processing time through a series of modifications to current methods. To do this, we sampled water for environmental DNA analyses from aquaria containing brook trout (*Salvelinus fontinalis*). We compared DNA recovered (total and species specific) in standard 48-hr DNA extractions to amounts of DNA from our modified extraction methods. By quantifying DNA obtained from both protocols and comparing the results, we can determine differences between the methods and subsequent analyses can be modified to expedite results. This is especially important for targeted eDNA monitoring, where rapid results are critical. Modifying these protocols can also provide economic benefits, in terms of supply and labor costs. The scientific and economic benefits of this study will have an immediate impact on scientists completing early detection studies in applied molecular research.

93-3 REVZEN, S; Univ. of Michigan, Ann Arbor; *shrevzen@umich.edu*

Moving with more legs is different: a geometric mechanics perspective

Most animals walking on land are not bipeds like us, nor are they quadrupeds like our close land-vertebrate relatives -- they have six or more legs, and usually move with three or more legs in contact with the ground at any time. Some new experimental results from robots and theoretical insights from mechanics suggest that such animals, even if they are running quickly and have sliding contacts, are moving in a regime akin to low Reynolds number swimming, and are in the "principal kinematic case" of geometric mechanics. I will present both empirical results and theoretical motivation in support of the claim that moving with more legs is fundamentally different, and in many ways simpler to control and analyze.

9-3 REYES, CL*; BENSON, B; LEVY, M; PIRES, A; PECHENIK, JA; DAVIES, SW; Boston University, Tufts University, Dickinson College, Tufts University; *chrislr@bu.edu*

Effects of ocean acidification on Crepidula fornicata physiology and gene expression across two life history stages

In addition to warmer ocean temperatures, increased atmospheric carbon dioxide emissions are causing reductions in seawater pH, termed ocean acidification. Here, we conducted a controlled laboratory experiment to investigate the effect of pH stress (pH 8.0, 7.6, 7.5) across two life stages of the common slipper shell snail *Crepidula fornicata*, an abundant and resilient species native to the littoral zones of Eastern North America. Shell and tissue growth rates were measured in 4 and 8 day old larvae and in juveniles 4 days after metamorphosis. The percentage of larvae that had become competent to metamorphose under the different pH rearing conditions was quantified on days 10 and 12. Genome-wide gene expression was profiled and correlated with these physiological data across all treatments and time points. We show that larvae exposed to pH 7.6 developed significantly less tissue relative to larvae exposed to pH 8.0. Larvae reared at lower pH (7.6 and 7.5) took longer to become competent to metamorphose, and gene expression data showed significantly different profiles across life stages and between treatments. This study highlights the importance of assessing the influence of ocean acidification across life history stages and demonstrates how transcriptomic plasticity can allow highly resilient organisms like *C. fornicata* to acclimate to drastically altered environmental conditions in the face of climate change.

28-3 REYES, ML*; GERARDO, N; PARKER, B; Clayton State University, Emory University, University of Rochester; *miguelreyes@clayton.edu*

The Impact of symbiotic bacteria on reproductive strategies and wing polyphenism in pea aphids responding to stress.

Environmental stressors can influence phenotypic plasticity and life-history characteristics. The response to stress may be further altered by the presence beneficial symbionts. Pea aphids (*Acyrthosiphon pisum*) harbor facultative symbionts that can provide protection against natural enemies and pathogens. Furthermore, aphids under stress are able to produce winged progeny that may be better able to migrate to safer habitats. The interaction between symbiosis and phenotypic plasticity, and their interactive effect on aphid fitness, remains unclear. In this study, we investigate how stress via crowding drive shifts in fecundity and production of winged offspring, and how symbionts influence the process. In the winged morphotypes, energy needed for wing maintenance may lead to trade-offs with other traits, such as reproduction or symbiont maintenance. Thus, we explore the influence of symbionts on production and fitness of wing/wingless morphs across two generations. Crowding resulted in increased production of winged offspring and shifts in fecundity rates, however, presence of symbionts did not interact with crowding. Stress on first generation mother aphids did not have cross-generational impacts on second generation adults, where variation in fecundity was strictly based on the presence of secondary symbionts and presence/absence of wings. Our study suggests a complex interaction between beneficial symbionts and environmental stressors. Winged aphids have the advantage of being able to migrate out of danger with more ease, but energy needed for wing production and maintenance may come with reproductive costs for their mothers and for themselves, and, in certain cases, these costs are altered by symbionts.

S3-4 REYNAGA, CM*; AZIZI, E; Duke University, University of California, Irvine; *crystal.reynaga@duke.edu*

Trade-offs of power amplification on compliant substrates

From frogs to fleas, many biological systems utilize power amplifying mechanisms to achieve fast accelerations. Power amplification can have varied performance outputs using the same set of components. To better understand how the quality of the latch can optimize for varying conditions, we reduce the complexity of the system to a lower level of organization where we can independently control the latch dynamics and mechanical properties of the substrate. Here, we ask how latch quality and substrate stiffness affects elastic energy recovery from compliant substrates. We present a simple hypothetical model that explains key features of latch dynamics on compliant substrates. We test this model, which suggests less-rigid (less ideal) latches perform optimally on complaint substrates. We develop a reduced *in vitro* muscle preparation to test the performance of the latch mechanism on compliant substrates. We use the plantaris muscle-tendon-unit of a bullfrog (*Lethobates catesbeianus*) as the motor and spring in-series connected to two servomotors; one that simulates unlatching (rapid muscle shortening as a result of joint extension) and a second that simulates a reactive complaint substrate. We test elastic energy recovery during tendon recoil from various compliant substrates and latch velocities. We found slower latch velocities recover more energy from compliant substrates. Our work decouples the latching mechanism to test key features of latch and spring dynamics on variable substrates. We suggest ‘less-ideal' latches may be most optimal for efficient performance on variable substrates regardless of relative compliance.

133-6 RICCI, C/A*; FUESS, L/E; MANN, W/T; CHAKRABARTY, J; JINKS, L/R; MYDLARZ, L/D; University of Texas at Arlington; *cricci@uta.edu*

Proteomic Characterization of Immune Responses and Post-infection Dynamics of Eunicea calyculata to late stage Eunicea Black Disease

Coral reefs are highly productive ecosystems that have been facing drastic declines in recent decades. Increased frequency in disease outbreaks contribute considerably to these declines, yet many coral diseases are poorly understood. In 2013, a novel disease infecting soft corals in the genus *Eunicea* was observed in Florida, USA. This disease was identified by extreme black pigmentation resulting from melanin deposition into the coral tissue. The etiological agent of this disease is as of yet unknown and was thus generically named "*Eunicea* black disease" (EBD). In diseased corals, previous histological analyses demonstrated tissue disorganization and previous transcriptomic analyses show a disruption of growth and reproductive processes. Here we present further characterization of EBD-infected corals using proteomic techniques to deepen our understanding of coral disease dynamics at the molecular level. Proteins from healthy and diseased coral samples were identified and quantified using nanospray mass spectrometry. Preliminary results show increased expression of proteins involved in inflammatory pathways in diseased corals, suggesting inflammation as a primary response to the pathogen responsible for EBD. Antimicrobial elements were also upregulated in diseased corals, along with GTP binding elements and nitric oxide producing elements. These data layered with previous transcriptomic data can inform late-stage consequences of infection and can therefore provide insight into coral resilience after a disease outbreak.

14-6 RICE, MA*; GALINDEZ, S; OPHIR, AG; Cornell University; *mr868@cornell.edu*

Female biased sex ratios lead to multi-male mating and mixed paternity in socially monogamous female prairie voles

When, how often, and with whom to mate are fundamental questions that directly impact the mating system of a population and that have tremendous implications for the evolutionary process in general. Although these questions have been fairly well studied in males, comparatively few studies have focused on investigating female mating tactics or reproductive decision-making. Here we asked how differential access to mates influences the occurrence of mixed paternity and overall reproductive success in socially monogamous female prairie voles (*Microtus ochrogaster*). We created male- and female-biased sex ratios of prairie voles living in semi-natural outdoor enclosures for approximately four weeks. After trapping, we ran paternity analyses to determine the identity and number of mating partners females had and the number of offspring each female produced. Counter to our original expectation, we found that when males outnumbered females, females had fewer mating partners and mixed paternity was rare. However, when females outnumbered males, females had multiple partners and high rates of mixed paternity. Although we did not determine which animals had formed pairbonds, these data are consistent with other studies that suggest that males preferentially impose pairbonding on females through mate guarding. This idea is reinforced by the result that females' reproductive success (number of offspring) increased as a function the number of male mating partners they had, regardless of the sex ratio context.

P1-205 RICHARDS, JC*; VECCHIONE, M; University of North Carolina at Chapel Hill, Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution; *jaredunc@live.unc.edu*

The Diversity and Distribution of Cephalopods in the Charlie-Gibbs Fracture Zone

In the summer of 2009, NOAA surveyed the nekton fauna of the fracture zone on the Mid-Atlantic Ridge halfway between Iceland and the Azores as a small-scale follow-up to a previous large-scale Norwegian expedition. Midwater sampling by NOAA with a Norwegian Krill Trawl resulted in 64 discrete-depth samples from 12 stations at depths from near-surface to 3000 m. An additional seven bottom samples were collected with a large trawl at depths of 2000-3500 m. The expedition collected 471 cephalopods in ca. 24 species. For comparison, over 50 hours of ROV submarine video from the Norwegian expedition was viewed to determine diel migratory patterns of the most common species of cephalopod in the region, *Gonatus steenstrupi*. We found that trawl stations below the subpolar front were generally most diverse. Cluster analysis showed that bottom trawls were more dissimilar in species composition than midwater trawls. Unlike in the ROV observations, the small *Gonatus steenstrupi* from trawl samples did not participate in diel vertical migration; suggesting that juveniles in the samples are ecologically distinct from those visible in submersible videos.

S3-6 RICHARDS, Christopher T.*; EBERHARD, Enrico A.; COLLINGS, Amber J.; The Royal Veterinary College, University of Portsmouth; *ctrichards@rvc.ac.uk*

Energy flow across segments in multi-body systems: a case study in frogs

A frog jump is both simple and difficult to comprehend. The centre-of-mass (COM) follows a 2D path; it accelerates diagonally upward, then traces a predictable arc in flight. Despite this simplicity, the leg segments trace intricate trajectories to drive the COM both upwards and forwards. Because the frog sits crouched with sprawled legs, segments must pivot, tilt and twist; they solve a long-recognised problem of converting non-linear 3D motion of the leg segments to linear 2D motion of the COM. We use mathematical approaches borrowed from robotics to address: How do frogs manipulate the flow of kinetic energy through their body to influence jump trajectory? We address: 1) Transfer of motion through kinematic transmission and 2) transfer of motion through dynamic coupling of segment mass-inertia properties. We used a quaternion-based approach to explore how non-linear leg motions convert to nearly linear/planar torso motion for effective jumping. We found that segment rotations follow nearly linear paths not in Euclidean space, but in 4D unit quaternion space. The shank acted as a steering rod to transmit motion from hip and ankle joints to influence upward versus forward motion of the torso. Additionally, we developed a multi-body simulation to explore how segment acceleration induces rotations at neighbouring segments (without bi-articular muscles). Frogs famously extend their back early in jumps. We found that this ilio-sacral joint rotation causes counterbalancing torques which are potentially used to tune the extent and timing of elastic energy storage-release in tendons. Thus, this inertial coupling mechanism is likely crucial not only for fine-tuning the flow of kinetic energy among segments, but also for modulating the direction of travel.

96-3 RICHARDS-ZAWACKI, CL*; ROBAK, M; ROLLINS-SMITH, L; RICHARDS-ZAWACKI, Corinn; University of Pittsburgh, Tulane University, Vanderbilt University; *cori.zawacki@pitt.edu*

Effects of temperature on the efficacy of amphibian skin defenses

A clearer understanding of how changes in the environment affect the immune defenses of animals is needed in order to predict the impact and dynamics of emerging wildlife diseases. Due to its dramatic effects on the physiology of animals, their microbiomes, and their pathogens, temperature may be a key variable modulating the level of protection an animal's defenses can provide. We investigated how temperature and two cutaneous defenses, the skin microbiome and antimicrobial peptides, affect the susceptibility of frog hosts to infection by the causative agent of amphibian chytridiomycosis, *Batrachochytrium dendrobatidis* (*Bd*). To do this, we manipulated either the bacterial community or antimicrobial peptides present in the skin mucus of susceptible hosts prior to exposing them to *Bd* under two different ecologically relevant temperatures. We predicted that frogs with reduced skin bacterial communities and antimicrobial peptides would be more susceptible (i.e., less resistant to and/or more tolerant of *Bd* infection) than frogs with intact or augmented (by addition of a known antifungal bacterium) mucosal defenses. However, we also predicted that these interactions would be temperature dependent, with higher temperatures increasing the protective capabilities of skin defenses. While temperature alone seems to have impacted the likelihood and intensity of *Bd* infection, a frog's ability to survive (i.e., tolerate) a heavy *Bd* infection was best explained by interaction between temperature and the cutaneous bacterial community. Both temperature and exposure to *Bd* affected the production of antimicrobial skin peptides, with frogs at higher temperatures producing more peptides and also surviving longer with a heavy *Bd* infection. These results may have important implications for the disease mitigation strategies for amphibians and other taxa threatened by disease in a changing climate.

108-7 RICHTER, MM*; SCALF, CE; PULLUM, KB; COOPER, LN; ASHLEY, NT; Western Kentucky University; *melanie.richter@wku.edu*

Effect of Polar Daylight on the Adrenocortical Response to Stress in Arctic-breeding Passerine Birds

Animals that spend the summer in Utqiaġvik, AK (71°N, 156°W) experience 24h daylight for >2 months. Among species that experience these conditions are two migratory passerine birds, the Lapland longspur (*Lapponicus calcarius*, LALO) and the closely related snow bunting (*Plectrophenax nivalis*, SNBU). LALO nest in open tundra and can experience high rates of nest failure (~16% success, 2018), whereas SNBU are cavity nesters and have high fledging rates (~83% fledge, 2018). For this study, we were interested in whether these different predation pressures altered the daily rhythms in adrenocortical response. We hypothesized that LALO (exposed to high predation) would exhibit little to no hourly variation in adrenocortical response to stress compared with SNBU (low predation). Free-living birds of both species were captured throughout the polar day and blood samples were collected at <2 (baseline), 10, and 30 min post-capture. Plasma was assayed for corticosterone concentration using ELISA. For LALO, no discernible diurnal rhythm in corticosterone levels was detected. SNBU, however, showed a significant rhythm in baseline corticosterone levels (Circwave harmonic regression, p=0.02, f=4.09, r^2=0.1007), but not in stress-induced levels. This study suggests that a lack of diurnal variation in ground-nesting LALO may represent an adaptation to the round-the-clock predation experienced at their nests.

125-3 RIDDELL, EA*; IKNAYAN, K; WOLF, BO; SINERVO, B; BEISSINGER, SR; Univ. of California, Berkeley, Univ. of New Mexico, Univ. of California, Santa Cruz; *riddell.eric@gmail.com*

Evaporative cooling stress links body mass to the collapse of desert bird communities

Climate change threatens to increase rates of extinction by pushing organisms beyond their physiological limits, but we still lack an adequate understanding of the mechanisms that link organismal stress to population-level responses to climate change. Ecological predictions of climate change are primarily hindered by the complex nature of the climate-organism relationship and the lack of long-term ecological responses to climate. Here, we evaluated the potential for physiological stress associated with homeothermy to predict the recently discovered collapse of the desert bird community over the last century. We developed a physiologically-structured model to predict the stress associated with offloading excess heat via evaporative cooling as a mechanism driving decline. Our analysis revealed that the degree of evaporative cooling stress on hot days predicted the decline in occupancy over the last century. Large-bodied species experienced a greater increase in EHL demand than small-bodied species given the same change in air temperature over the last century. These predictions also provided a mechanistic understanding underlying intraspecific reductions of body mass in response to warm climates, a pattern described by Bergmann's rule. Empirical reductions in body size from our species resulted in as much as 13% savings in water needed for homeothermy on an average day in the desert. Our predictions of future responses to climate change suggest a high probability for further population declines in desert environments due to stress associated offloading excess heat under future climate change.

P2-204 RIEGLER, MS*; GILL, BC; ANEMONE, RL; NACHMAN, B; STOCKER, MR; University of Florida , Virginia Tech, UNC Greensboro, UNC Greensboro, Virginia Tech ; *msr2322@ufl.edu*

Isotopic Geochemistry as an Ecological Proxy in Lizards: Diet and Aridity in Early Eocene Squamates

The paleoecology of lizards over time is largely unknown. This paucity of data is problematic for understanding lizard response to climate change, especially considering the climate change modern species are currently experiencing. Fortunately, Cenozoic hyperthermals represent comparable events to today's perturbations, and many Paleogene deposits preserve squamate fossils. Inferring paleoecology has historically been based on form equaling function, correlating certain features with certain behaviors. Though this applies to certain taxa, there are many confounding examples. Stable isotope geochemistry, however, provides an independent test for several ecological parameters. We developed a novel method examining isotopic ratios in enamel as a proxy for ecology and applied it to lizards, providing new data testing the connection between squamate morphology, their diets, and the environments they occupy. We analyzed $\delta^{18}O$ and $\delta^{13}C$ ratios from tooth enamel in five extant lizard species. We found trophic separation in $\delta^{13}C$ values, and indications of aridity through $\delta^{18}O$ values. We applied this framework to extinct squamates from an Early Eocene herpetofaunal assemblage, where we identify xenosaurid and glyptosaurine squamates as well as alethinophidian snakes. The xenosaurid is one of the youngest representatives of *Restes rugosus*, and we provide the first testable hypothesis of its ecology. $\delta^{13}C$ results indicate an insectivorous or carnivorous diet for both lizard taxa, representing the first hypothesis for the diet of *R. rugosus*. $\delta,^{18}O$ results indicate a wet, warm environment, confirming prior hypotheses of a tropical community present in the Western Interior of North America in the Paleogene.

128-6 RIESER, JM*; ASTLEY, HC; GONG, C; CHONG, B; SCHIEBEL, PE; RANKIN, JW; MICHEL, K; NICIEZA, A; HUTCHINSON, JR; HATTON, RL; CHOSET, H; GOLDMAN, DI; Ga Tech, Univ. Akron, Carnegie Mellon, Royal Vet College, Univ. Oviedo, Oregon State, Carnegie Mellon; *jennifer.rieser@physics.gatech.edu*

Comparative geometric mechanics of animal locomotion in dissipative environments

Biological terrestrial locomotors navigate through a wide range of terrain, from tall grasses to forest floors to the yielding sandy substrates of the desert. These movements result from the coupling of environmental interactions with cyclic self-deformation patterns generated by animals. In animal movement on and within granular media, body inertial effects are small compared to dissipation; further, granular Resistive Force Theory provides an accurate model of these highly damped interactions. These features, along with a low-dimensional representation of self-deformation patterns, allow for the application of a general locomotion framework, geometric mechanics, which was introduced by particle physicists in the 1980's to study swimming microorganisms. Recent advances in the theory have enabled application of this framework to continuous and hybrid systems and thus allow systematic comparison of body coordination patterns and morphology for locomotion of limbless and limbed animals. We find that undulatory snakes and lizards swimming within granular media use waveforms predicted to produce near-maximal displacements per undulation cycle. We find that the coordination between foot placement and spinal flexion observed in salamanders walking on the surface of granular media produces near-maximal displacements per gait cycle. These results highlight the broad applicability of these tools to understand coordination and self-deformation patterns in dissipative environments. We posit that movement on and within other dissipative environments (e.g., muds and leaf litter) could be amenable to these tools.

24-4 RIFAI, NM*; MYKLES, DL; Colarodo State University, Colorado State University; *nadarifai2008@yahoo.com*

Effects of Molt Induction Methods on Cyclic Nucleotide Phosphodiesterase Expression in the Decapod Crustacean Molting Gland

cAMP and cGMP, as second messengers, mediate the suppression of the crustacean molting gland (Y-organ or YO) by molt-inhibiting hormone (MIH). When MIH levels decrease, the YO transitions from the basal to the activated state and the animal enters premolt; such a 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. Seven PDE contigs were extracted from the YO transcriptome. qPCR was used to quantify the effects of molt induction by multiple limb autotomy (MLA) or eyestalk ablation (ESA) ± mTOR inhibitor rapamycin on the expression of PDE 1, 2, 4, 5, 7, 9, and 11 in *Gecarcinus lateralis* YO. In response to MLA, all 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 PDE4, 5, 7, 9, and 11 showed no significant changes by 7 and 14 days post-ESA. Rapamycin had no significant effect, as PDE mRNA levels were comparable to those of controls at all time points, indicating that PDE expression is not regulated by mTOR. The qPCR results were consistent with RNA-Seq data, showing similar trends of PDE expression in both MLA and ESA ± rapamycin. The data suggest that transcriptional regulation does not contribute to 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).

P3-109 RIMKEVICIUS, T*; JARRETT, A; IVANINA, AV; SOKOLOVA, IM; University of North Carolina at Charlotte, Charlotte, NC, USA, Department of Oral Biology, School of Dental Medicine, University of Pittsburgh, Pittsburg, PA, USA, University of North Carolina at Charlotte, Charlotte, NC, USA , Department of Marine Biology, University of Rostock, Rostock, Germany; *aivanina@uncc.edu*

Effects of salinity on activity of key biomineralization and acid-base regulation enzymes of Mercenaria mercenaria

The molluscan exoskeleton provides mechanical support and protection from predators and environmental stressors. The mantle edge (ME) and hemocytes (HCs) play a major role in molluscan shell formation. Salinity is one of the key stressors that affect bivalve populations and is predicted to be decreased in the future. The aim of this study was to determine how conditions unfavorable for $CaCO_3$ deposition would affect cell-mediated shell biomineralization process in bivalves. Adult hard shell clam *Mercenaria mercenaria* were exposed for two weeks to three salinities (30, 18 or 10) and activity of biomienralization and acid-base regulation enzymes (Na/K ATPase, H^+ ATPase, Ca^{2+} ATPase, carbonic anhydrase and chitin synthase) was measured in isolated ME cells and HCs. Salinity shifts has different effects on biomineralization enzymes from ME and HCs in clams. Activities of the studied biomineralization and acid base regulated enzymes from HCs was not affected by change in salinity, where Na/K ATPAse and Ca^{2+} ATPase activity in ME were elevated at intermittent salinity (18) compared to high (30) or low (10) salinity. Change in salinity regime had no effect of activity of carbonic anhydrase and chitin synthases in HCs or ME cells of clams.

P1-19 RIMKUS, B*; SHEHAJ, A; KONOW, N; UMASS Lowell; *barbora_rimkus@student.uml.edu*

Do Muscles with Distinct Fiber Architecture, Fiber-type Composition, and Mechanical Function have Different Modulatory Scopes for Power and Work Production?

Skeletal muscles are arranged in flexor-extensor groups to produce opposing joint movements and enable variations in cycle frequency (gait), duty-factor, and movement mechanics (operation as a motor, strut, or brake). However, it is unclear if flexors and extensors, which often vary in fiber architecture and composition, have equal scope for modulating power and work across movement conditions. To address this, we systematically varied stimulus phasing and cycle frequency parameters in the work-loop paradigm to dissect the modulatory scope of power and work output from two mouse hindlimb muscles; a fast-fibered, slightly pennate dorsiflexor (tibialis anterior; TA), and a mixed-slow fibered, plantarflexor (soleus; SOL) with near-parallel fiber architecture. We used literature values for mouse *in vivo* stride frequencies and duty factors for walk, trot, and gallop. Three stimulation phases were calculated to simulate muscle motor, spring, and brake performance. Our data suggest that SOL mostly operates as a brake (in line with available *in vivo* data) and TA as a motor or strut. SOL has the greatest modulatory scope and a clearer response to stimulus phasing than to variations in cycle frequency on power and work. However, comparing only the active work-loop portions reveal clear similarities in function between these muscles, consistent with the conserved contractile properties of vertebrate skeletal muscle. Perhaps unsurprisingly, muscle type appears to profoundly influence the modulatory scope of muscle performance. Our ability to measure from more than one muscle in a given individual provides a powerful framework for forthcoming evaluations of how mechanical insults and dietary variation shape muscle adaptability and performance.

13-4 RIMNICEANU, M*; SPONBERG, S; Georgia Institute of Technology; *martha.rimniceanu@gmail.com*

Moths are distractible fliers.

Animals moving in natural environments experience many simultaneous sensory cues. Visual scenes comprise task-relevant and irrelevant cues, and self-generated motion of the background. As vision research often uses salient widefield or target tracking cues, it remains unclear how animals parse multiple competing visual stimuli. *Manduca sexta* hawkmoths hover and track moving flowers. We explore how they contend with 3 types of external visual cues that may distract or aid in flower tracking: a stationary widefield cue, a stationary target (vertical bar) and an oscillating bar target. These cues may be ignored, linearly summed with the flower cue, or become distractors, which we assess as non-linear, context-specific effects on flower tracking. Figure/ground discrimination work in flies suggests that widefield cues may be processed independent of target motion, predicting no effect of the widefield cue on flower tracking. Linear dynamics typically capture moth flower tracking and describe the combination of multimodal sensory cues. We find that neither predicts the response to multiple visual cues. A stationary widefield cue improved flower tracking performance, decreasing tracking error at flower frequencies between 1.1Hz and 2.3Hz, where moths typically lag the flower and overshoot its position. In contrast, the oscillating visual cue did not impact flower tracking at any frequency except that of the bar, suggesting linearity. However, the specific gain and phase response at this frequency could not be predicted by linear combination or a rescaling of the bar stimulus. We conclude that given two distinct visual motion cues with differing task relevance, the signals combine nonlinearly to affect the primary task. Moths are distractible fliers, which may enable them to tune responses to cues in a context dependent way, for example to balance foraging and predator avoidance.

P1-24 RIORDAN, KC*; TAYLOR, JRA; West Chester University of Pennsylvania, Scripps Institution of Oceanography; *kr877841@wcupa.edu*

Mechanical Adaptions for Climbing in Grapsid Crabs

Vertical climbing is a biomechanically challenging behavior that many vertebrates and insects have mastered for their arboreal habitats. Less is known about arboreal crabs and their adaptations in overcoming the challenges of climbing. To gain insights into crab climbing, we compared the walking leg morphology and mechanics of two closely related crabs (family Grapsidae): the arboreal mangrove crab, *Aratus pisonii*, and the rocky intertidal shore crab, *Pachygrapsus crassipes*. *A. pisonii* lives and climbs in mangrove trees, whereas *P. crassipes* climbs rocks easily, but not trees. We hypothesized that mangrove crabs would require relatively shorter, stiffer legs and harder gripping structures (dactyls) to overcome gravity and maintain balance when scaling trees. Crab mass and carapace dimensions were measured (*A. pisonii*: N = 9; *P. crassipes*: N = 15), along with dimensions of the second pereopod. We also measured the flexural stiffness and failure strength of the meropodite, and the hardness of the dactyls. Results show that *A. pisonii* have relatively larger, more flexible meropodites than *P. crassipes*, which may aid them to cling to narrow branches. The meropodites of both species are similar in strength, but failed by buckling in *A. pisonii*, and cuticle fracture in *P. crassipes*, which likely reflects differences in cuticle morphology. There was no difference in dactyl hardness and stiffness between the species, suggesting that the dactyls are sufficient for gripping and supporting a crab on a variety of substrates. Overall, the walking leg morphology of grapsid crabs appears to require minimal modifications to enable vertical climbing, but a broader comparison among aboreal and non-arboreal crabs would yield greater insights into adaptations for tree climbing in crabs.

P2-176 RIPPE, JP*; BAUMANN, JB; CASTILLO, KD; DAVIES, SW; University of North Carolina at Chapel Hill, Boston University; *jpr6mg@gmail.com*

Coral Connectivity on the Belize Barrier Reef: Is Gene Flow Sufficient to Foster Reef-Scale Adaptation to Ocean Warming?

Rising ocean temperatures are often implicated in the widespread demise of coral reefs, as high temperatures can lead to a fatal breakdown of the relationship between coral hosts and their single-celled algal symbionts in a process known as coral bleaching. However, recent research has revealed that the effect of warming on corals of the same species may vary widely depending on their thermal history. Specifically, corals from nearshore reef habitats, which experience relatively extreme daily and seasonal seawater temperature fluctuations, have demonstrated higher tolerance to thermal stress than their forereef conspecifics, which experience more thermally stable conditions. Importantly, this intraspecific variation in thermal tolerance has also been shown to be heritable, implying that genetic linkage between resilient nearshore reefs and sensitive forereef populations could foster reef-scale adaptation to ocean warming. Here, we use restriction site-associated DNA sequencing to explore the fine-scale population genomics of the massive starlet coral, *Siderastrea siderea*, throughout the Belize Barrier Reef System. Tissue micro-samples were collected from 176 colonies of *S. siderea* across four pairs of nearshore and forereef sites in November 2014 and 2015. These sampling sites were intentionally selected based on their distinct thermal characteristics, where nearshore sites experience both warmer and more variable temperature conditions than those on the forereef. By resolving the patterns of genetic exchange between nearshore and forereef sites on the Belize Barrier Reef, this study provides insight into the prospect of dispersal-driven adaptation, which may be essential to the survival and evolution of Caribbean coral reefs as oceans continue to warm.

55-1 RITSON-WILLIAMS, R*; CUNNING, R; NUNEZ-PONS, L; SOGIN, E; NELSON, C; FORSMAN, Z; WILLIS, S; GATES, R; ALBRIGHT, R; California Academy of Science, Shedd Aquarium, Stazione Zoologica "Anton Dohrn", Max Planck Institute for Marine Microbiology, University of Hawaii at Manoa, Hawaii Institute of Marine Biology; *rritson-williams@calacademy.org*

Integrating Genomics to Better Understand Coral Resilience to Bleaching

Rising seawater temperatures threaten corals and bleaching events are increasing in extent and frequency. In both 2014 and 2015 corals in Hawai'i had extensive bleaching in response to high seawater temperatures. We tagged 40 pairs of coral colonies of two species, *Montipora capitata* and *Porites compressa*, and tracked their fate for three years. Within each species the tagged corals were selected so that one individual coral colony that bleached was adjacent to one colony that retained its dark color. We collected 23 tissue samples of each coral colony over a three year time period that encompassed two consecutive bleaching events and the recovery period after both bleaching events. Using amplicon sequencing we characterized the *Symbiodinium* community in each species of coral (ITS-2) and found that different coral species had different communities of *Symbiodinium*. The microbiome also differed between the coral species and was also different between bleached and unbleached colonies (16S). Using qPCR we quantified the clade and abundance of *Symbiodinium* in *M. capitata* over two years and found rapid recovery of symbiont abundance after bleaching but little symbiont shuffling. Using ezRAD we did not detect loci that correlated to bleaching resistance but we did uncover hidden genetic diversity within *P. compressa*. Overall, there was less than 10% mortality in the tagged coral colonies. By integrating analyses on the same coral colonies we can study the factors that might contribute to how corals resist and recover from thermal stress.

P2-228 RIVERA, G*; WHALEN, M; WORTHINGTON, AM; Creighton University; *gabrielrivera@creighton.edu*

Do Patterns of Fluctuating Asymmetry Reflect the Strength of Natural and Sexual Selection in the Sand Cricket (Gryllus firmus)?

Selection, both natural and sexual, has the ability to produce morphologies that increase performance of individuals. While many studies examining this ability have focused on the effects of shape, for many paired structures the degree of symmetry has also been shown to impact performance. As a result, the morphology of traits vital for locomotion (e.g., legs or wings) or reproduction (e.g., sexually-selected ornaments or weapons) may rely more heavily on overall symmetry to remain functional than other non-vital structures, and therefore may be more developmentally constrained. Fluctuating asymmetry (FA) refers to deviations from perfect symmetry in bilateral structures and may serve as a useful tool in evaluating the strength of selection acting on individuals. In the sand cricket (*Gryllus firmus*), two distinct morphs with unique life histories exist: Short-wing (SW) morphs are incapable of flight, but have high reproductive potential as early adults; long-wing (LW) morphs have enlarged wings for dispersal, but produce fewer offspring and do so later in life. Early reproduction in SW morphs places stronger selective pressures on reproductive structures, while dispersal in LW morphs places stronger selective pressures on locomotor structures. Because the two morphs rely on different body structures to maximize their fitness, and because many structures used by males for courtship and fighting do not serve the same function for females, we expect to see predictable differences in FA both between morphs and sexes.

107-7 RIVERA, AS; Univ. of the Pacific; *arivera@pacific.edu*

An Open Education Resource (OER) textbook and curriculum for EvoDevo

Evolutionary Developmental Biology (EvoDevo) seeks to explain many of the confusing and fascinating patterns we see in nature, igniting student interest immediately. Moreover, it is highly integrative - allowing students with backgrounds in either Genetics, Development, Evolution, or Anatomy and Physiology to explore other fields from a steady reference point. Despite this, there is no recent textbook suitable for the undergraduate/first year graduate classroom. This places the burden on each instructor to summarize the last 15 years of progress in the field. To alleviate this, I have created a free open source EvoDevo curriculum consisting of a core textbook as well as reading and discussion guides for external sources. The entire curriculum can be edited, remixed and augmented in LibreTexts, making it a useful starting point for a custom course. The curriculum is designed for sophomores through first year grad students and does not assume any coursework past Introductory Biology. Discussion questions range greatly in difficulty and complexity, giving both beginner and more advanced students challenging topics to consider. Currently, the course contains modules on Developmental Processes (Fertilization, Cleavage, and Gastrulation), EvoDevo concepts (Patterning, Evolvability, Novelty, and Regionalization), and primers on Genetics and Gene Regulatory Networks. While some of these topics are covered in other undergraduate-level courses, my curriculum uses EvoDevo case-studies to make the topics relevant to the class. EvoDevo is a broad and quickly moving field, making it particularly amenable to an Open Textbook. Students, researchers, and instructors are invited to edit, enhance, and add to the current topics with the ultimate goal of creating a resource pool of EvoDevo teaching modules that can be mixed and matched for individual courses.

P1-11 RIVERA, AS; AHMADYAR, S; EITOKU, J; HA, J; IMADA, K; LEE, A; LO, A; NAVALTA, K*; PANAGLOTOPOULOS, A; VU, K; YEE, C; Univ of the Pacific; *arivera@pacific.edu*

Student-generated resources for an EvoDevo Open Textbook (OER)

When creating new resources for teaching and learning biology, two huge problems immediately arise: What do students want to learn? and What do students already know? Here we describe an attempt to address these problems through a "Learning by Teaching" approach. Undergraduate and first year Master's students volunteered to edit and illustrate an Open Textbook for their EvoDevo course or to write case-study modules for inclusion in the text. EvoDevo's integrative nature and combination of philosophy and experimental approaches make it a natural choice for student contribution. To make these resources, students must think deeply about this complex field and consider how Evolution, Development, Genetics, Anatomy, and Physiology act together and on each other to produce life's riotous diversity. The end product is a resource written at an undergraduate-appropriate level with approachable language, illustrations, and topics.

75-6 RIVEST, EB*; JELLISON, BM; NG, G; SATTERTHWAITE, EV; BRADLEY, HL; WILLIAMS, SL; GAYLORD, B; Virginia Institute of Marine Science, Bowdoin College, Univ. of California, Davis, Univ. of California, Davis, James Madison University; *ebrivest@vims.edu*

Effects of Global Environmental Change on Marine Systems: Insights from Sensory Ecology

Human-caused environmental change will have many non-lethal and indirect impacts on organisms due to altered sensory pathways, with consequences for a plethora of ecological interactions. An integrated view of how multiple aspects of environmental change will impact multiple sensory pathways and consequently ecological processes is needed to better anticipate broader consequences for marine ecosystems. Here, we present a synthesis of effects of global change on marine sensory ecology. Our literature review supports several predictions for how particular sensory pathway steps are affected by aspects of environmental change. Global ocean change impacts production and reception/processing of cues and signals in similar ways, likely through physiological stress. The energy budget may be reallocated to prioritize physiological maintenance over the function of these sensory steps. Global ocean change affects transmission of cues/signals in other ways. During transmission, cues/signals are directly influenced by conditions of the environment outside of the organism. Finally, a relatively small number of studies have been conducted at the interface of global environmental change and marine sensory ecology. We highlight key knowledge gaps that merit further investigation, including how effects on individual sensory processes will integrate to shape species interactions. Because many ecological and evolutionary interactions rely on sensory processing, impairment of sensory pathways may be a primary mechanism underlying impacts of global ocean change on marine ecosystems.

111-4 ROBART, AR*; NAVARRO, W; ZUNIGA, H; WATTS, HE; Washington State University ; *ashleyrobart@gmail.com*

Social Pairing Influences Behavior and Physiology Near Termination of Migration in a Facultative Migrant

Spring migratory movements of obligate migrants are consistent, both in terms of where animals travel to and from, as well as when these movements occur. In contrast, facultative migrants have unpredictable migrations that vary both spatially and temporally. While recent studies have examined the environmental cues used to initiate facultative migration, it is still unclear what information facultative migrants use to terminate their migratory movements. We examined whether the addition of a social partner influences the termination of migratory behavior in pine siskins (*Spinus pinus*), a nomadic, irruptive migrant. We videotaped birds in late spring to assess their nocturnal activity as an indicator of migratory status (migratory/non-migratory) and then either paired birds that differed in their migratory status or left migratory and non-migratory birds unpaired as controls. We videotaped birds immediately after pairing and again 10 days later. We also measured body parameters that are indicative of migratory preparations when birds were initially assigned a treatment and at the end of the experiment. Migratory and non-migratory control birds did not change their nocturnal activity levels during the experiment, but the paired migratory birds decreased their nocturnal activity. The decrease in nocturnal activity in the paired migratory birds was evident on the first night after pairing. Paired migratory birds also decreased their mass and fat deposits. These results suggest that social pairing can quickly synchronize not only migratory behavior, but also physiology. This would increase group cohesiveness and the likelihood that individuals that migrate together would ultimately terminate movements at the same time, which may ultimately facilitate the transition to breeding.

25-5 ROBERTS, NS*; MENDELSON, TC; University of Maryland Baltimore County; *nat17@umbc.edu*

Measure of a Mate: The Role of Male and Female Pattern Elements in Conspecific Mate Choice

Behavioral isolation is a powerful reproductive barrier, often responsible for the maintenance of species boundaries between closely species. In sexually dimorphic species where males are showy, females are often attributed as the choosy sex; thus, many studies of behavioral isolation focus on the role of female preferences for conspecific male stimuli. There is also good evidence that male phenotype between species are more distinct than female phenotypes, lending to this idea that female mate choice is the driving factor in the maintenance of species boundaries. However, there is increasing evidence for the role of male mate choice, suggesting that males of sexually dimorphic species may play a larger role than formerly thought in behavioral isolation. In the banded darter (*Etheostoma zonale*) data show that males have strong preferences for conspecific females when presented with both a conspecific and heterospecific female stimuli. Previous studies have shown that male color and pattern are both important factors in mate recognition for female *E. zonale*, however there has been no comparable study done to identify how males recognize conspecific females, which lack the elaborate and species-specific ornamentation present on males. Using a machine learning approach, we identified which pattern elements of male and female *E. zonale* were able to significantly predict species-identify significantly above chance. We then used animated darter stimuli and video-playback to test the role of female color and pattern elements on male mate choice.

P1-278 ROBERTS, A.S.*; DONATELLI, C.M.; University of California, Davis, Tufts University ; *asroberts@ucdavis.edu*

Fish Motion in the Ocean: Predicting Swimming Kinematics from Vertebral Morphology

Fish have evolved a variety of swimming mechanisms to move through diverse habitats. While some fish primarily use pectoral and caudal fin motion to propel themselves through water, others use body undulation to locomote. Many studies have characterized kinematic features of swimming mechanisms such as swimming speed, tail beat frequency, and bending period, but few have examined the role of vertebral morphology in swimming kinematics. Because the vertebral column is a conserved skeletal element in fishes and the main structure used for body stiffening during swimming, it can provide critical information about fish swimming kinematics. In this study we used a statistical model originally created to predict 3D swimming kinematics in elongate fishes to predict 2D swimming kinematics in six fish species that vary from elongate (elong.) to deep-bodied (non-elong.). We collected swimming kinematic data from video trials and measurements of vertebra size and shape from CT scans of *Anoplarchus purpurescens* (Stichaeidae; elong.), *Pholis ornata* (Pholidae; elong.), *Ammodytes personatus* (Ammodytidae; non-elong.), *Ophiodon elongatus* (Hexagrammidae; non-elong.), *Myoxocephalus polyacanthocephalus* (Cottidae; non-elong.), and *Cymatogaster aggregata* (Embiotocidae; non-elong.). Specifically, we collected size and shape data from multiple centra along the vertebral column to predict body bending amplitude along the length of the body during swimming. This estimate was then compared to the bending amplitude measured from fish swimming videos. We determined that vertebral morphology has significant power to predict body bending amplitude during swimming in both elongate and non-elongate fishes, with centrum body length and cone angle being the most important factors.

S3-2 ROBERTS, TJ; Brown University; *thomas_roberts@brown.edu*
Some Challenges of Playing with Power
Many studies of the flow of energy between the body, muscles, and elastic elements highlight advantages of the storage and recovery of elastic energy. The spring-like action of structures associated with muscles allows for movements that are less costly, more powerful and safer than would be possible with contractile elements alone. But these actions also present challenges that might not be present if the pattern of energy flow were simpler, e.g., if power were always applied directly from muscle to motions of the body. Muscle is under the direct control of the nervous system, and precise modulation of activity can allow for finely controlled displacement and force. Elastic structures deform under load in a predictable way, but are not under direct control, thus both displacement and the flow of energy are at the mercy of the mechanical interaction of muscle and forces associated with movement. Studies on isolated muscle-tendon units highlight the challenges of controlling such systems. A carefully tuned activation pattern is necessary for effectively cycling of energy between tendon and the environment; most activation patterns lead to futile cycling of energy between tendon and muscle. In power-amplified systems, "elastic backfire" sometimes occurs, where energy loaded into tendon acts to lengthen active muscles, rather than accelerate the body. Classic models of proprioception that rely on muscle spindle organs for sensing muscle and joint displacement illustrate how elastic structures might influence sensory feedback by decoupling joint movement from muscle fiber displacements. Exactly what challenges complex flows of energy within muscles, elastic elements and motion might present to sensory-motor mechanisms is largely unexplored.

35-5 ROBERTSON, JK*; BURNESS, G; MASTROMONACO, G; Trent University, Peterborough, The Toronto Zoo, Toronto; *joshuarobertson@trentu.ca*
Stress-induced peripheral hypothermia: Role of the sympathetic nervous system in avian thermal modulation
Overwhelming evidence suggests that both acute and chronic stress physiology can be predictive of condition, thermoregulation, and survivorship, and are therefore measures of interest to ecologists. Over the past 30 years, however, the role of the sympathetic nervous system (SNS) in mediating stress-induced physiological changes has been alarmingly neglected for favor of glucocorticoid driven processes. For this reason, we investigated the influence of time-averaged SNS activity on stress-induced, thermal profiles, using captive, wild-caught Black-capped Chickadees (*Poecile atricapillus*; n = 20). Recent research has suggested that the temperature of peripheral tissues (specifically, tissues surrounding the eye) is responsive to acute stress in birds. Here, we tested whether such stress-induced, peripheral hypothermia is maintained under chronic stress exposure, using a paired experimental design whereby each individual was exposed to a thirty day period of randomly assigned, daily stressors ($n_{stressors}$ = 6, time per exposure = 20 min), and a control period of equivalent duration. Thermal profiles were monitored daily using remote infra-red thermography and compared between treatment types. Secondly, we investigated whether peripheral thermal profiles were best explained by time-averaged SNS or glucocorticoid profiles, by quantifying deposition of metanephrine, normetanephrine, and corticosterone in feathers grown throughout experimentation, and testing correlations with mean eye temperature across individuals. Our results support persistent, peripheral hypothermia under chronic stress exposure ($p = 0.024$, $t = -2.19$, $n_{measurements}$ = 7967), when ambient temperature is accounted for. Correlations between temperature of peripheral tissues and time-averaged endocrine profiles will be discussed.

P2-261 ROBERTSON, JC; Westminster College, PA; *robertjc@westminster.edu*
Characterizing Gill Pigmentation in Paddlefish (Polyodon spathula)
Juvenile and adult paddlefish have striking, darkly-pigmented gill respiratory lamellae. To investigate this unusual condition, a visual assessment protocol was developed to quantify the degree of pigmentation of gill filaments. Four groups of larval and early-juvenile stage (30, 50, 60 and 100 day post-hatch) fish were analyzed. For each fish, multiple gill arches from both the right and left sides were studied. Each filament in a gill arch was scored, based on the extent to which pigment was observed along the length of the filament. This approach thus assessed the degree of gill pigmentation in post-hatch, early paddlefish development. Results clearly indicate a dramatic change in gill pigmentation over the period examined. There was no gill pigmentation in 30 day post-hatch fish, low but increasing levels in 50 and 60 day fish, and markedly higher pigment in gills of 100 day post-hatch fish. Pigment changes appeared to be independent of numbers of filaments per gill arch, which stabilized at 50 days post-hatch. Histology indicates that primary lamellae melanocytes are responsible for paddlefish gill pigmentation. These cells are generally perivenous - localized adjacent to and along the central vascular elements of the filament. Results are considered in light of possible functions associated with gill pigmentation as well as developmental origin and activation of gill melanocytes.

P2-108 ROBICHEAUX, JR*; ALMOND, GF; PERKINS, HR; GOFF, CB; FORSBURG, ZR; GABOR, CR; Texas State University, TSU; *jar475@txstate.edu*
Validating and Using Water-Borne Hormone Methods with Tadpoles: ACTH Challenge, Recovery Time, Repeatability, and Optimal Rearing Designs
We monitored the physiological health and stress response of tadpoles using non-invasive water-borne assays to measure the stress hormone, corticosterone (CORT). We performed an adrenocorticotropic hormone (ACTH) challenge and additional experiments to explore repeatability, recovery time from stress, and optimal rearing methods for Rio Grande Leopard frog, *Rana berlandieri*, tadpoles. Tadpole CORT release rates were higher after ACTH injections, validating water-borne hormone methods. We then examined the recovery time for water-borne CORT release rates after exposure to an external stressor (agitation). CORT began to decline after 2h and had recovered after 6h indicating that it is important to wait an extra hour (or up to 6hrs) if you want to avoid measuring the initial stress response. We also examined CORT and repeatability using water-borne hormones from tadpoles reared individually vs isolated in groups. We then examined whether these tadpoles show an acute stress response after exposure to agitation. Individuals isolated in groups showed hypothalamus-pituitary-interrenal axis (HPI) activity in response to a stressor and higher CORT release rates on D7. These individuals also lost mass by D7, whereas individuals reared alone did not. Repeatability was high for both treatments. These results indicate that either rearing method is viable but the two methods differ in their physiological costs. We show that the water-borne hormone method allows for repeated measures from individuals when the experiment is appropriately designed to consider social behavior of the species. This will be useful in management and health assessment of wild and captive populations of *R. berlandieri*.

P1-204 RODAS, AM*; WRIGHT, RM; BUIE, LK; AICHELMAN, HE; CASTILLO, KD; DAVIES, SW; Boston University, Boston University & Harvard Medical School, University of North Carolina at Chapel Hill, University of North Carolina at Chapel Hill & Boston University, University of North Carolina at Chapel Hill; *amrodas@bu.edu*

Environmental variation and plankton genetic diversity across inshore and offshore coral reefs

In the ocean, environmental variation in light and temperature can influence the genetic diversity and structure of plankton communities. Here, we aimed to characterize environmental variation and its influence on plankton communities from the Bocas Del Toro Archipelago reef complex in Panamá. We visited eight reef sites: four inshore and four offshore reefs to characterize variation in thermal and light profiles across sites. Temperature loggers were deployed at each reef site for one year and a light data logger was deployed at each site at midday to quantify noon light values. Plankton tows were conducted in triplicate at midday and 18S DNA metabarcoding was used to characterize plankton communities. In addition, at STRI Point, plankton communities were characterized in the morning and evening in order to investigate the effect of time of day. We found that inshore sites exhibited larger variation in temperature, while offshore sites exhibited increased light levels. However, these environmental differences across reef type did not drive differences in plankton communities. We found no significant differences in overall plankton community composition or genetic diversity across time of day, reef type (inshore/offshore), or reef site. Instead we found that several specific taxa were significantly enriched at different sites, but overall plankton communities appear relatively panmictic across our study sites. This study is limited to taxonomic differences detectable by 18S metabarcoding: the possibility of selection on other genetic loci within these taxa remains a possibility and future work should investigate fine scale population structure within a genus.

P3-44 RODERICK, WRT; CHIN, DD*; CUTKOSKY, MR; LENTINK, D; Stanford University; *wrtr@stanford.edu*

Preparing for takeoff and sticking the landing: Bird behavior and biomechanics at the interface of flight and surface locomotion

Birds frequently take off and land on branches that vary widely in size and texture. Yet, despite our familiarity with these behaviors, we do not fully understand how they integrate the use of aerodynamic support from their wings, energy transfer from their legs, and friction at their feet to take off and land so reliably. To study these behaviors in detail, we made high-speed recordings of Pacific parrotlets (*Forpus coelestis*) taking off and landing from instrumented perches with a range of surface properties and diameters. The kinematics and force/torque measurements give insight into the biomechanics and control strategies that enable birds to perform these maneuvers consistently on different perches. By further integrating these results with experimental data on the contact mechanics at the foot-surface interface, we develop a model of the force space in which birds can maintain a stable grasp during takeoff and landing. 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 aerial robots.

P1-176 RODRíGUEZ-SALTOS, CA*; DUQUE, FG; Psychology Department, Emory University, Atlanta, GA 30322, Neuroscience Institute, Georgia State University, Atlanta, GA 30302; *carodr5@emory.edu*

Precise Decrease in the Tempo of the Song of a Tropical Wren

Animals often time their behavioral displays with precision. Sometimes, they change the tempo of the display in a single session, as some southern nightingale-wrens (*Microcerculus marginatus*) do with their songs. In these songs, the tempo is slowed down due to a progressive increase in the lengths of silence intervals between syllables. The first interval lasts around 0.7 seconds, while the last interval may reach 12 seconds. By analyzing several songs downloaded from the database Xeno-Canto, we found that a simple pattern describes the increase in interval duration. The duration of a given interval was equal to that of the preceding interval plus a time constant. For example, in a single rendition, a bird added 0.6 seconds of silence to each consecutive interval, even when the preceding interval was already more than 10 seconds long. The timing of the intervals did not seem to follow Weber's law, because the time constant was precisely kept despite increasing silence intervals. It is unknown how nightingale-wrens achieve this remarkable degree of precision in timing. Not all nightingale-wrens, however, change the tempo of their songs; songs vary considerably across populations. Geographic song variation in oscine passerines, such as the Nightingale-Wren, is often a by-product of vocal learning. If the same applies to southern nightingale-wrens, then the change in tempo in some populations may be at least partly learned.

S11-1 RODRIGUEZ, RL*; EBERHARD, WG; Biological Sciences, Univ. of Wisconsin-Milwaukee, USA, Escuela de Biología, Univ. de Costa Rica, Costa Rica; Smithsonian Tropical Research Institute, Panama; and Museum of Natural Science, Louisiana State Univ., USA; *rafa@uwm.edu*

Sexual Selection and Static Allometry: the Importance of Behavior and Function

Extreme trait elaboration and showiness are the reason Darwin recognized sexual selection as distinct from natural selection. Extreme trait sizes, and disproportionately large traits in large individuals, were thought to be part of this pattern. However, traits under sexual selection vary widely in how they scale on body size (in allometry), from positive (as just mentioned) to negative allometry (with large individuals having disproportionately small traits). To explain this variation, we note that size per se has different consequences in different types of sexual competition. In interactions involving weapons and threats, disproportionately large traits in large individuals are favored due to the combination of two reasons: larger individuals usually win in physical fights; and threats are used by smaller individuals to avoid unwinnable fights with larger individuals. In addition, the reproductive payoffs from threats are often higher for large males, and larger males need greater differences in trait sizes to successfully threaten other large males due to Weber's Law. Positive allometry is thus predicted for structures (including many weapons) used in threats. Courtship signals, in contrast, convey many types of information to the female that are not necessarily related to the male's size, so positive allometry is not predicted. A comparative study of the allometry of male traits with "pure" threat vs "pure" courtship signal functions yielded strong support for these predictions, throwing light on the range of allometries that have evolved in sexual traits.

23-7 RODRIGUEZ, LF*; COLE, J; FENNER, J; COUNTERMAN, B; Mississippi State University; *lfr36@msstate.edu*

GENETICS OF STRUCTURAL COLORATION IN PIERID BUTTERFLY WINGS

Butterfly wing color patterns result from an arrangement of monochromatic scales containing both chemical pigments and a delicate architecture that can cause interference or diffraction of light, generating iridescent colors. The latter mechanism, structural coloration, serves essential functions such as conspecific recognition, mate choice, and communication in many species. Despite the ecological importance of this trait, little is known about the molecular mechanisms underlying the development of structural-based color patterns. The Southern Dogface butterfly, *Zerene cesonia*, exhibits sexually dimorphic development of ultraviolet wing reflectance. Males posses a UV patch on the forewing that results from nanoscale structures on the wing scales, which are absent in females. This dimorphism offers an excellent opportunity to explore the genetic mechanisms involved in pattern formation and cyto-structural variation. We used RNA-seq data from imaginal wing discs through late larval and pupal development to identify genes involved in the regulation of color pattering and scale structure formation. We identified clusters of co-expressed genes that correspond to the pre-pattering and structural scale differentiation stages. In the latter, we found differential expression of the *doublesex* gene (*dsx*); however, we did not find the typical splicing patterns of *dsx* found in other insects. We are working on the structural and functional characterization of a novel female *dsx* transcript, and exploring the pathways involved in pre-patterning of the male UV patch. Our results offer some of the first insights into genetic mechanisms that regulate scale structural coloration.

138-6 ROGALLA, S*; SHAWKEY, MD; D'ALBA, L; Ghent University; *svana.rogalla@ugent.be*

Dark or Bright for a Faster Flight? The Thermal Impacts of Wing Coloration on Flight Performance

Flight performance is a critical aspect of avian biology. However, few studies have yet addressed the impacts of wing coloration on birds' flight. Dark colors are known to absorb more solar radiation than light colors, which would lead to a faster increase in surface temperature. A warmer dorsal wing surface could lead to decreases in air density above the wing and in turn decrease the drag. Yet, solar heat gain can be extremely sensitive to changes in wind speed, which in our case resembles the flight speed. In this study, we tested the prediction that darker wings, that are exposed to the direct radiation of the sun, heat up to higher temperatures than brighter wings. We further suggest that the temperature difference would persist even during flight, hence including high aerial convection rates. We tested the impact of solar energy and flight speed on the surface temperatures of differently colored wings in three steps: 1) We modeled the temperatures for altering solar radiation intensities and wind speeds. 2) We took reflectance measurements and thermal images of live birds that were exposed to changing intensities of solar radiation to compare those temperatures with our predicted values. 3) We exposed differently colored stuffed wings in a wind tunnel and measured their surface temperatures for altering radiation intensities and wind speeds. The heating experiment in the wind tunnel served as a sensitivity analysis to test the interactions of various factors during flight: The impact of solar radiation, wind and wing coloration on wing surface temperature as well as the impact of wing surface temperature on air density above the wing. With this study we want to show to what extend flight is affected by wing coloration, solar radiation and flight speed. Thereby we may address a new important factor in avian flight and migration.

58-6 ROGERS, LS*; VETTER, BJ; MENSINGER, AF; University of Minnesota Duluth, University of Washington; *roger710@d.umn.edu*

The Effect of Light Stimuli on Dark-Adapted Visual Sensitivity in Invasive Silver (Hypophthalmichthys molitrix) and bighead (H. nobilis) Carp

Since the accidental introduction of silver (*Hypophthalmichthys molitrix*) and bighead (*H. nobilis*) carp into the southern part of the United States in the 1970's, these fishes have migrated northwards through the Mississippi River Drainage and now threaten the Laurentian Great Lakes. To control the further expansion of these invasive carp, fisheries managers have been working to develop effective non-physical barriers, which include underwater strobe lights used either alone or paired with sound and/or bubbles. To optimize the use of potential optical deterrents, it is necessary to understand the visual sensitivity of the fishes and the impact these non-physical barriers have on the visual system. Using the electroretinogram (ERG) technique, dark-adapted silver and bighead carp were found to possess broad visual sensitivity between 470 nm to 620 nm, with peak spectral sensitivity at 540 nm and 560 nm, respectively. To assess the impact of strobe light on vision, dark-adapted silver, bighead, and common carp (*Cyprinus carpio*), were exposed to three different 5-second trains (100, 200, or 500 ms on/off flashes) of white light (760 lumen) and the recovery of visual sensitivity was determined by measuring the b-wave amplitude of the ERG. For all species, the longest recoveries were observed in response to 500 ms flash trains. Recovery to > 50% for silver and bighead carp took up to 360 s, while common carp took up to 240 s. Recovery time to ≥ 90% for silver carp took 702.0 s ± 89.8 (mean ± 1 SE), bighead carp 648.0 s ± 116.0, and common carp 480 s ± 180.0. The results suggest that exposure to strobe light can temporarily depress visual sensitivity, which may render optical barriers less effective.

40-5 ROGERS, D.C.; University of Kansas; *Branchiopod@gmail.com*

Predatory Anostracans Alter Growth of Prey Anostracans (Crustacea: Branchiopoda)

The fairy shrimp genus Branchinecta has two, giant, predatory species (B. gigas and B. raptor) that prey primarily on the normal sized congener B. mackini, and to a lesser extent on B. readingi. These prey species occur commonly in temporary pools across western North America, while the two predatory species are limited to far fewer locations. I observed that the prey species are far larger and more physically robust in basins where the predator is present than in other sites. Though field collections and lab cultures, I found that the prey species growth rates (length and volume) were different depending upon whether a predator species was present or not, and was different in the presence of each predator species. Prey species growth rates not only increased greatly in the presence of the predatory species, but matched the growth rate of the predator species present. This increased growth rate only occurred when the predator species was present, and could be induced when water from cultures or wild populations of the predatory species was added to predator free prey cultures, even from populations that had never encountered the predator species in the wild. Predator species actively consumed smaller prey species individuals of subsequent cohorts, but ignored the larger, first cohort individuals, unless no other prey was present. This suggests that the prey species have found a "size refugium", where they may be too large for predator consumption, and that this change in growth rate is triggered by some sort of kairomone produced by the predator. The fact that populations which have never encountered the predator species also demonstrate this change in growth, suggests that these species encountered each other early in their evolution.

42-4 ROGERS, DD*; PERLMAN, BM; AZIZI, E; LAPPIN, AK; California State Polytechnic Univ., Pomona, Univ. of California, Irvine; *ddrogers@cpp.edu*

Effects of Temperature on Dragonfly Nymph Prey-Strike Performance

During the aquatic nymphal stage, dragonflies possess a modified labium that functions as a high-speed raptorial appendage used in prey capture. During labial protraction, a preparatory phase of slow protraction is followed by the release of a latched knob-like structure in the elbow region of the labium, which results in a fast strike phase during which the appendage rapidly accelerates. The strike phase appears ballistic in nature, where relatively slow muscle contraction during the preparatory phase stores energy in associated elastic elements, and this energy is recovered via rapid recoil of the elastic structures once the latch disengages to produce a high-speed movement. We hypothesized that the performance (e.g., velocity, acceleration, work, power) of the non-ballistic preparatory phase should be thermally dependent, whereas the performance of the prospectively ballistic strike phase should have low thermal dependence. To test this hypothesis, individual nymphs were imaged (two cameras at 1000 Hz) capturing prey (California blackworm) at 15C, 25C, and 30C. We found that temperature affects the average and peak velocity of labial protraction during both the preparatory and strike phases. The effect on the preparatory phase was expected, given that the shortening velocity of ectotherm muscle is known to be temperature dependent. For the strike phase, high observed velocities indicate the presence of a ballistic component to the movement. However, because strike phase performance also is thermally dependent, it cannot be a purely ballistic movement like those observed in some invertebrate and vertebrate systems.

P3-169 ROHLF, CM*; HUSAK, JF; Univ of St Thomas; *rohl0016@stthomas.edu*

The Effects of Varying Immune Challenges on Performance Traits in Green Anole Lizards

In order to maximize lifetime reproductive success, organisms often must allocate limited energetic resources to life history traits that are important to survival, such as immunity and locomotion. Consequently, trade-offs can occur between traits, depending on the traits' energetic costs and energy available to each organism. Previous work on green anole lizards reveals that when energy is forced to be allocated to endurance performance via exercise training, the immune system becomes compromised. We tested whether the opposite relationship was true. We predicted that when an organism faces an immune challenge such as infection and/or wound healing, its endurance performance should decrease, with greater immune challenges decreasing performance more. To test this prediction, male and female green anoles were given or not given cutaneous wounds and underwent two rounds of lipopolysaccharide (LPS) or saline injections to induce an integrated immune response. We measured endurance, sprint speed, and bite force before and after each round of injections. We predicted performance to vary in the order: no wound-no LPS > no wound-LPS > wound-no LPS > wound-LPS. However, we found that neither wound healing nor LPS injections affected any performance trait in either males or females after the first injections. However, after the second round of injections, LPS decreased bite force, suggesting a lack of motivation due to sickness behavior.

84-5 ROHR, JR*; CIVITELLO, DJ; COHEN, JM; ROZNIK, EA; SINERVO, B; DELL, AI; University of South Florida, Emory University, Memphis Zoo, Univ. of California, Santa Cruz, National Great Rivers Research and Education Center; *jasonrohr@gmail.com*

The Complex Drivers of Thermal Acclimation and Breadth in Ectotherms

Thermal acclimation capacity, the degree to which organisms can alter their optimal performance temperature and critical thermal limits with changing temperatures, reflects their ability to respond to temperature variability and thus might be important for coping with global climate change. Here, we combine simulation modelling with analysis of published data on thermal acclimation and breadth (range of temperatures over which organisms perform well) to develop a framework for predicting thermal plasticity across taxa, latitudes, body sizes, traits, habitats and methodological factors. Our synthesis includes >2000 measures of acclimation capacities from >500 species of ectotherms spanning fungi, invertebrates, and vertebrates from freshwater, marine and terrestrial habitats. We find that body size, latitude, and methodological factors often interact to shape acclimation responses and that acclimation rate scales negatively with body size, contributing to a general negative association between body size and thermal breadth across species. Additionally, we reveal that acclimation capacity increases with body size, increases with latitude (to mid-latitudinal zones) and seasonality for smaller but not larger organisms, decreases with thermal safety margin (upper lethal temperature minus maximum environmental temperatures), and is regularly underestimated because of experimental artefacts. We then demonstrate that our framework can predict the contribution of acclimation plasticity to the IUCN threat status of amphibians globally, suggesting that phenotypic plasticity is already buffering some species from climate change.

P3-5 ROMANOVICH, LA*; VOLTZOW, J; Univ. of Scranton, PA; *janice.voltzow@scranton.edu*

Anemones in Hot Acid: The Effects of Elevated Temperature and Enhanced Carbon Dioxide on Anemones and their Symbionts

Like some corals, many sea anemones have symbiotic relationships with photosynthetic dinoflagellates of the family Symbiodiniaceae, sometimes referred to as zooxanthellae. In the process known as bleaching, this relationship is disrupted and the dinoflagellates are expelled from the cnidarian tissue, causing it to turn white. We were curious about the individual and combined effects of two consequences of climate change, rising sea surface temperature and ocean acidification, on bleaching. We exposed individuals of the symbiotic anemone *Exaiptasia pallida* to one of three treatments: warmed water, water acidified by the addition of carbon dioxide, or water that was warmed and acidified, and compared their responses with controls. Data from chlorophyll fluorometry and images from fluorescence microscopy permitted us to monitor symbiont loss. Anemones in the heated and combined treatments showed different rates of bleaching whereas those in the acidified treatment showed no loss of symbionts. These results indicate that there is a complex interaction between the effects of elevated temperature and enhanced carbon dioxide on this symbiotic relationship. Thus, it is important to take both factors into account when evaluating the potential impact of climate change on bleaching.

BERN-1 ROMERO, L. Michael; Tufts University;
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Scared, Cold, and Hungry - Stress from the Arctic to the Equator

We are fast approaching the 100-year anniversary for using the word "stress" to describe the suite of behavioral, physiological, and endocrine responses of animals to noxious environmental stimuli. Biomedicine has made substantial progress during these years in understanding and defining stress in humans and laboratory animals. The growing consensus has settled on a theoretical model that emphasizes three main features: stressors, characterized by unpredictability and uncontrollability, that initiate a response; a suite of responses elicited by stressors that help the animal survive; and the pathological consequences of the overuse of that suite of responses (chronic stress). However, this model has had poor success in predicting and explaining data from wild animals coping with their natural environments - animals that are often scared, cold, and hungry. Decades of data from different species and different habitats have shown why the traditional biomedical model is insufficient. This insufficiency led to the development of Reactive Scope, a model of stress that focuses on the wear-and-tear inherent to utilizing a stress response. Reactive Scope can improve the predictions and interpretations of stress responses in wild, freely-behaving animals.

S5-2 ROMERO, L. Michael; Tufts University;
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How Truly Conserved is the "Well-Conserved" Vertebrate Stress Response?

The vertebrate stress response is considered to be a highly conserved suite of responses that are evolved to help animals survive noxious environmental stimuli. The two major pathways of the stress response include the catecholamine release that is part of the autonomic nervous system and comprises the immediate fight-or-flight response, and the slower release of corticosteroids from the hypothalamic-pituitary-adrenal axis that help orchestrate longer-term responses. These two pathways are present in every vertebrate yet examined, and the anatomical and physiological architecture underlying these pathways are consistent. Despite these structural similarities, however, recent data indicate substantial temporal and species variation in the actual regulation of these pathways. For example, activation of both pathways varies seasonally in some species but not others, and responses of both pathways can be extensively modulated by an individual's previous experience. Given this variation, it is perhaps not surprising that it is proving difficult to correlate individual stress responses with differences in fitness outcomes. The likely solution is to focus on multifactorial downstream measurements of catecholamine and corticosteroid function, rather than solely on hormone titers. Moving beyond hormone titers could help clarify how the stress response can increase fitness.

P2-67 RONALD, K.L.*; HURLEY, L.M.; Indiana University;
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Neural Activation of the Inferior Colliculus to Multimodal Stimuli in the House Mouse (Mus musculus)

Communication signals are often complex and span multiple sensory modalities. While much research has focused on male signal production contributing to female preferences, females often give their own multimodal cues during intersexual communication events. Our findings suggest that the behavior of male mice () is affected by the presence of female vocalizations and olfactory cues. Nevertheless, the neural encoding of these multimodal stimuli is poorly understood. Here we investigated the degree of neural activation in the inferior colliculus (IC), a region of the auditory midbrain, to the presence of multimodal stimuli (vocalizations and olfactory cues). We have evidence to suggest that multimodal cues may affect the activity of neurons in the IC, suggesting that primary auditory brain regions may be sensitive to cues in other sensory modalities. These preliminary analyses support the prediction that the combination of modalities increases the density of c-fos positive neurons in the inferior colliculus. These results support the hypothesis that social and sensory context and multimodal integration are encoded by brain regions prior to the cortex.

P2-13 ROOT, ZD*; JANDZIK, D; MEDEIROS, DM; University of Colorado Boulder; *zaro7315@colorado.edu*

Straw, Sticks, and Bricks: Understanding Vertebrate Musculoskeletal Evolution through Fibrillar Collagens and their Diversification

Fibrillar collagens are a metazoan novelty that are a critical part of the extracellular matrix of muscle, skeleton, skin, and connective tissues. Comprised of three families of genes (Clade A, Clade B, Clade C), they underwent considerable duplication and neofunctionalization in jawed vertebrates (gnathostomes). Previous work has suggested that ancestral chordates possessed four fibrillar collagens (2 A's, 1B, 1C) while most jawed vertebrates have eleven (5 A's, 4 B's, 2 C's). We asked whether the expansion of this gene family coincides with gnathostome morphological novelties by investigating these genes in the sea lamprey *Petromyzon marinus*, an early diverging jawless vertebrate. To do this, we used phylogenetics and synteny to identify fibrillar collagen orthologs in the sea lamprey. We then performed *in situ* hybridizations on lamprey embryos for these genes across developmental stages, preparing plastic sections to identify tissue-specific expression. Overall, we have identified eight new fibrillar collagen genes in the sea lamprey and categorized their expression during head morphogenesis. We believe that *Petromyzon marinus* may have twelve fibrillar collagen genes (7 A's, 4 B's, 1 C), four being lineage-specific duplicates. Our phylogenetic and syntenic analyses have identified orthologs of Clade A / C genes in lamprey with strong certainty while Clade B remains uncertain, possibly due to more divergence. Our *in situ* hybridizations reveal expression of these genes that is less tissue-specific than their gnathostome orthologs. Lastly, we discuss how the the duplication and specialization of these collagens may have been involved in the diversification of musculoskeletal tissues during vertebrate evolution.

P1-248 ROQUENI, MT*; GOSLINER, TM; The Evergreen State College, The California Academy of Sciences ; *masotrg@gmail.com*
Discovering Genetic Differences Among Morphologically Similar Thecacera from the Temperate and Tropical Oceans
The nudibranch genus *Thecacera*, belonging to the family Polyceridae (Nudibranchia, or sea slugs), was first described by Montagu in 1813 with *T. pennigera* as the type species. To date, there are 7 described species in *Thecacera*. *Thecacera* is characterized by a radula adapted for feeding on arborescent bryozoans, and rhinophores that are sheathed with a cup and gills with elongated post-branchial appendages. Within this genus there are a variety of color patterns. Morphological identification alone has not been sufficient to separate species within this genus. There has been previous work done to describe species within *Thecacera*. However, there is evidence that many species have been misidentified. Our research shows that some species represent described species of *Thecacera*, while other species have distinct color patterns otherwise unknown in the genus. We used Sanger sequencing to sequence 3 genes (16S, COI, and H3), and made an alignment with Mesquite. Maximum likelihood and Bayesian trees were generated with the Figtree program (v 1.4.3). Our combined morphological and genetic data suggest that within *Thecacera* there has been misidentified individuals that belong to existing species, as well as seven new species that have genetic variance, thus doubling the known diversity within this genus. These new species include taxa with cryptic and divergent color patterns. Internally, we found other radular and reproductive differences that correlate with the genetic differences that were detected. The significance of this work lies in our improved understanding of species richness, so that we can better understand how to manage and protect biodiversity and the ecosystems that support it.

76-1 ROSA, M; PADILLA, DK*; Conneticut College, Stony Brook University, Stony Brook University; *Dianna.Padilla@stonybrook.edu*
When Size Doesn't Matter: Food Choice By Bivalve Larvae
Bivalves are some of the most important suspension feeders in aquatic systems. Adult bivalves pump water with cilia on the ctenidia (gills) and capture particle on the gills. Adults are highly selective in the algae they remove from the water column. Recent work has shown that selectivity on the gills depends on passive mechanisms resulting from the interactions between physicochemical properties of algae and the mucus of individual species of bivalves. Larvae of bivalve do not have gills, and instead use crowns of large cilia, on the velum, for both locomotion and feeding. We conducted experiments to determine whether similar properties of algae are important for particle selection for feeding as for adults. We found that larvae of different species of bivalves feed at different rates on different species of algae when presented alone as well as in combination with other algae. In some cases, there were differences in the algae or particle consumed by the larvae, independent of size. We also found that in some cases larval feeding preferences changed through ontogeny, suggesting that the mechanisms for food selection are different than for adults.

S1-4 ROSELL, JA; Instituto de Ecología, Univ. Nacional Autónoma de México; *julieta.rosell@iecologia.unam.mx*
Understanding the Causes of Diversity of a Multifunctional Structure: the Case of Bark in Woody Plants
Most biological structures carry out multiple functions. Focusing on only one of these functions to make adaptive inferences overlooks that manifold selection pressures and tradeoffs shape the characteristics of a multitasking structure. Focusing on single functions can only lead to a partial picture of the causes underlying diversity and the evolutionary origin of the structure in question. We illustrate this discussion using bark as a study case. Bark comprises all the tissues surrounding the xylem (wood) in woody plants. Broadly, bark includes an inner and mostly living region and an outer and mostly dead one. Of all plant structures, these two main regions have the most complex anatomical structure and ontogenetic origin involving two (sometimes three) different meristems. Traditionally, the wide morphological, structural and functional diversity of bark has been interpreted as the result of the selective pressures imposed by fire regime. However, recent research has emphasized that in addition to fire protection, bark carries out several other crucial functions for plants including translocation of photosynthates, storage of starch, water, and other compounds, protection from herbivores, pathogens and high temperatures, insulation, mechanical contribution, photosynthesis, and is likely involved in xylem embolism repair. All these functions are crucial for plant performance and are involved in synergistic (e.g., storage of water and insulation) and trade-off relationships (e.g., protection from fire vs photosynthetic activity). Focusing on only one of these functions (e.g. protection from fire) will provide an incomplete picture of the selective forces shaping bark diversity and will severely hinder our incipient understanding of the functional ecology of this crucial region of woody stems.

P1-270 ROSENBLOOM, JE*; GIDMARK, NJ; Knox College; *jerosenbloom@knox.edu*
Quantifying physiological constraints of prey capture in Centrarchid fishes
Predator-prey interactions put attributes of the predator (e.g. biting force) against those of the prey (e.g. body size). These attributes are constrained by both physical phenomena (e.g. lever mechanics) and physiological phenomena (e.g. force-length and force-velocity performance of skeletal muscle) in the predator. The force-velocity relationship is important for prey capture in centrarchid fishes, because these species often captures elusive prey. This family of fishes has a wide range of feeding behaviors, 2 examples of this are: largemouth bass swim quickly and then close the mouth over the prey, whereas bluegills suction feed. Both of these species need rapid mouth closure to preclude prey escape. These species also vary in skeletal anatomy; largemouth have long jaws, whereas bluegills have short jaws. Other members of this family fall along the continuum between largemouth and bluegills, and exhibit a range of jaw shapes and attack behaviors. Jaw-closing performance is governed by the interaction of skeletal anatomy and muscle physiology, and yet only skeletal anatomy and behavior have been deeply investigated to date in this group. We measured jaw-closing velocity across forces (i.e. the force-velocity relationship) in 5 species: Redear Sunfish,*Lepomis microlophus*; Black crappie,*Pomoxis nigromaculatus*; Largemouth bass, *Micropterus salmoides*; Bluegill, *Lepomis macrochirus*; and Green sunfish, *Lepomis cyanellus*. After accounting for the effects of skeletal leverage, we found that crappie and largemouth show similar patterns of force and velocity, whereas green sunfish, bluegill sunfish, and redear sunfish show similar patterns with each other. Interestingly, green sunfish skeletal anatomy is more similar to crappie and largemouth than it is to either other sunfish species. These results suggest that in this group, physiological performance of the jaw-closing muscle does not necessarily mirror lever mechanics in the skeleton.

83-2 ROSENDALE, AJ*; DUNLEVY, ME; MCCUE, MD; BENOIT, JB; Mount St. Joseph University, University of Cincinnati, Sable Systems International; *andrew.rosendale@msj.edu*

Molecular, physiological, and behavioral shifts during prolonged starvation in the American dog tick

Ticks are obligate blood feeding arthropods that spend most (> 95%) of their lives off host in an unfed state where they must contended with extended periods of starvation between blood meals. The success of these arthropods as vectors of disease depends on their ability to survive prolonged off-host periods; however, little is known about the underlying mechanisms associated with tick starvation. In this study, we examined the transcriptomic, bioenergetic, and behavioral changes of American dog ticks, *Dermacentor variabilis*, as starvation progressed. Ticks utilized glycogen and lipid, and later protein as energy reserves as starvation continued with the mobilization of endogenous nutrients being facilitated by proteolysis and autophagy. Tick metabolic rate was expectedly low, but showed a slight increase as starvation extended beyond 12 weeks, possibly reflecting an increase in energetically costly processes such as host-seeking behaviors. Starved ticks had higher activity levels, increased questing behavior, and augmented expression of genes related to feeding. The shifts in gene expression and associated behavioral and physiological processes are critical to allowing these parasites to exploit their ecological niche as extreme sit-and-wait parasites.

7-1 ROSS, S.D.*; NAVE, G.K.; SOMERS, K.; DAVIS, B.; GRUSZEWSKI, H.; HALL, N.; POWERS, C.; SCHMALE, D.G.; Virginia Tech; *sdross@vt.edu*

Aerial dispersal devices inspired by autorotating plant seeds

Autorotating winged seeds known as samaras flutter gracefully to the ground from towering maple and ash trees. The extended fall of the seeds provides an inspiration for artificial devices that gently deliver sensors or other packages, dropped from aircraft or drones. We have designed and tested 3D-printed replicas as well as scaled-up versions of maple seeds which can carry a payload safely to the ground when dropped from a significant height. This design could be used to disperse sensors or provide a parachute-less airdrop of needed supplies in an emergency situation.

P3-80 ROSSO, A. A.*; NICHOLSON, D.; CHUNG, A. K.; CURLIS, J. D.; KNELL, R.; GRANER, T.; LOGAN, M.; MCMILLAN, W. O.; COX, C. L.; Georgia Southern University, Queen Mary University, University of Michigan, Smithsonian Tropical Research Institute; *adam@rosso.com*

Ectoparasites and the Expression of Sexual Signals in a Tropical Lizard

Sexual signals are often associated with costs that can impact fitness through survival, reproduction and fecundity. The brightly colored dewlap of anoles can be used as a sexual signal to attract mates. In general, females are attracted to males with the larger and more brightly colored dewlap. The expression of these dewlaps may be associated with costs in the form of ectoparasites, such as mites. However, there is little known about the costs associated with sexual signals and ectoparasites. We studied the relationship between mite intensity, habitat use, and expression of a sexual signal in the Panamanian slender anole (*Anolis apletophallus*). Specifically, we tested whether the larger sexual signal in males relative to females resulted in increased mite intensity. We found that males had significantly more mites than females, but this difference was not driven by physiological or ecological factors like body temperature or habitat use. Interestingly, the difference in total number of mites between the sexes was driven by the preponderance of mites on the dewlaps of males, with similar amounts of mites on other regions of the body for both sexes. Males had many more mites on their dewlap than females and dewlap mite intensity increased with dewlap size for males. Our study shows that expression of sexual signals in male slender anoles are associated with ectoparasite costs. More broadly, these results suggest that sex-specific costs imposed by ectoparasites could structure the evolution of sexual signals.

P1-79 ROSTON, RA*; ROTH, VL; Duke University; *rachel.roston@duke.edu*

The Evo-Devo of Cetacean Cranial Telescoping: A New Empirical Framework and Discoveries

Cetaceans (e.g. whales, dolphins, porpoises) possess some of the most extreme and peculiar skulls among mammals. In most mammals, the skull bones fit together in a conserved pattern and structure of articulation. Within this conserved arrangement, variation arises through changes in the relative sizes, shapes, and orientations of cranial bones. In contrast to those in a typical mammal, the bones in cetacean skulls overlap extensively in a phenomenon known as cranial "telescoping." While telescoping in cetacean skulls was first described in detail in 1923, many questions remain about its origins, function, and general biology. Here we will present a new evolutionary-developmental framework for telescoping phenomena aimed at promoting empirical progress toward understanding how cetacean skull structures have diverged from the ancestral mammalian bauplan. We will also discuss some of the empirical discoveries we have made within this new framework.

85-5 ROSVALL, KA*; GEORGE, EM; BENTZ, AB; Indiana University, Bloomington; *krosvall@indiana.edu*

Seasonal changes in aggression, testosterone, and gene regulation in a cavity-nesting bird: insights on the challenge hypothesis in females

The challenge hypothesis suggests that variation in testosterone (T) secretion is shaped by trade-offs between competition and parental care in male vertebrates. Female competition is also widespread; however, it is not clear whether or how the challenge hypothesis applies to females. Here, we explore this issue in a series of studies using a seasonal comparative approach with the tree swallow (*Tachycineta bicolor*), a cavity-nesting bird for which challenges from prospecting rivals pose a threat to territorial females. In this system, more aggressive females are more likely to obtain a nesting cavity, and trade-offs between aggression and maternal care are influenced by T. We show that, during territorial establishment, females are capable of elevating T, and gene expression analyses suggest that they actively produce the potent androgen dihydrotestosterone as well. During incubation, T levels rapidly decline, but seasonal changes in aggression do not mirror these hormonal shifts. Gene expression analyses of muscle and brain suggest that androgen processing may be sustained from territory establishment through incubation, perhaps providing local, tissue-specific mechanisms that may support aggression when systemic T levels are low. These seasonally variable patterns of behavior, hormones, and gene expression hint at potentially adaptive tissue-level mechanisms that may allow females to respond to social competition while also mitigating trade-offs with parental care.

P2-160 ROWSEY, LE*; KIEFFER, JD; SPEERS-ROESCH, B; University of New Brunswick; *lrowsey@unb.ca*

Why Be Cool? Behavioral Thermoregulation and Physiological Recovery After Exhaustive Exercise in Juvenile Brook Charr (Salvelinus fontinalis)

The effects of temperature on post-exercise recovery in fishes are widely studied, but questions remain about which metabolic processes are most important in driving temperature-dependent recovery. For example, is it more advantageous to recover oxygen debt faster at cooler temperatures or remove lactate quickly at warmer temperatures? We examined the influence of temperature on recovery processes and thermoregulation following exhaustive exercise in juvenile brook charr (*Salvelinus fontinalis*). Fish were acclimated to and exercised at 15°C, then allowed to recover at either 15°C or 10°C while their excess post-exercise oxygen consumption (EPOC) was measured. Additionally, post-exercise metabolite levels were measured in fish assigned to one of three thermal recovery regimes (i) 6 hr recovery at 15°C, (ii) 6 hr recovery at 10°C, as well as (iii) 3 hr recovery at 10°C followed by a 3 hr recovery at 15°C (to simulate behavioral thermoregulation). We found that EPOC was completed more rapidly at 10°C compared with 15°C, but the lower temperature had the trade-off of hindering the recovery of plasma lactate and osmolarity levels. Specifically, post-exercise plasma lactate and osmolarity remained elevated for the entire recovery period in fish recovering at 10°C, whereas these variables recovered fully by 6 hr in fish from the other two recovery regimes. Currently, we are completing behavioral preference experiments to determine if brook charr will utilize behavioral thermoregulation and which physiological advantage they choose to optimize: EPOC recovery or lactate clearance.

36-7 ROWSEY, LE*; REEVE, C; SPEERS-ROESCH, B; University of New Brunswick; *lrowsey@unb.ca*

Do Thermal Constraints on Physiological Performance Drive Winter Dormancy in Fish?

Winter dormancy (an inactive, fasting, slow metabolism state) is used by certain fishes to endure the frigid and food-poor winter and thus persist at poleward latitudes. However, little is known about the mechanisms and drivers of winter dormancy. Temperature affects physiological and biochemical processes, with performance being facilitated at temperatures close to the thermal optimum (T_{opt}) and constrained at the thermal extremes. We hypothesized that winter dormancy is a response to constraints of low temperature on physiological performance. We measured the thermal sensitivity of three key physiological performance metrics (burst swim performance, maximum metabolic rate, and aerobic scope) in the winter-dormant cunner (*Tautogolabrus adspersus*), which we determined enters dormancy below 7.3±0.6°C. Performance was measured after (i) acute exposure to temperatures between 2-26°C or (ii) long-term acclimation (5+ weeks) to 2, 5, 8, 11, and 14°C. As expected, performance declined with cooling below the T_{opt} in both exposure groups. In acutely exposed fish, the thermal sensitivity of performance was much greater below the dormancy threshold temperature than above, suggesting a major constraint of cold. However, at 2°C, acclimated cunner had greater performance compared to acutely exposed cunner; thermal sensitivity of acclimated fish was lower than acutely exposed fish (Q_{10} of 1.1-2.0 vs. 3.9-4.3 between 2-8°C, respectively). Thus, dormant cunner compensate for effects of winter cold on swimming and aerobic performance, similar to cold-active species. We conclude that thermal constraints on anaerobic swim performance and aerobic metabolism are not major drivers of winter dormancy in fishes.

P2-39 ROY, T*; SURIYAMPOLA, PS; FLORES, J; LOPEZ, M; MARTINS, EP; Arizona State University; *troy15@asu.edu*

Habitat Features and Artificial Selection Determine Color Preferences in Zebrafish Danio rerio

The sensory drive hypothesis has been supported by many previous studies that show animals to preferentially approach colors that are also used as sexual signals. Studies in fish have shown modifications in such preferences depending on the ambient water color. Turbidity alters ambient color and organisms may compensate for visual obscurity in turbid environments through shifts in visual sensitivity towards higher wavelengths. Here, we asked whether zebrafish from more turbid habitats developed an increased preference for a prominent body color blue (on their stripes) or a presumed habitat color green, and whether relaxed selection on domesticated zebrafish has altered this preference. We subjected zebrafish from 4 populations (3 wild & 1 hatchery reared) to a dichotomous choice task (blue vs green door). We found the wild fish to show a clear preference for green over blue, while the domesticated fish entered green and blue doors equally often. The preference for green was strongest in fish from a turbid stagnant water population. Wild fish may tend to associate the green color with features of the natural habitat consisting of vegetation or with the diet consisting of microalgae and zooplanktons. This indicates that vegetation/food color and not turbidity might influence development of visual preference in wild zebrafish. Domestication has eliminated the preference, perhaps explaining why other zebrafish studies yield conflicting results on color preferences. These results are also suggestive of zebrafish offering an intriguing example where a color signal does not drive visual preferences.

S5-7 RUBENSTEIN, DR; Columbia University;
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Epigenetic mechanisms for plasticity in coping with environmental change
If organisms are to persist in the face of climate change, they must be able to deal not only with increasing temperatures, but also greater climatic variation. One of the primary ways animals cope with environmental change is through phenotypic plasticity, the ability to respond to environmental cues through phenotypic adjustment. In birds, the hypothalamic-pituitary-adrenal (HPA) axis allows individuals to rapidly adjust their responses to environmental change. Despite much work exploring HPA function under different environmental conditions, we still lack a thorough understanding of how the HPA axis has evolved in species living in naturally variable and unpredictable environments. Using superb starlings (Lamprotornis superbus), which inhabit a range of East African environments where rainfall varies within and among years, I will explore the molecular mechanisms that underlie plasticity in the HPA axis. First, I will show how annual variation in rainfall during development influences plasticity in the form of DNA methylation of the glucocorticoid receptor, which in turn affects their fitness later in life. Next, I will explore how patterns of DNA methylation in other HPA-related genes, as well as across the entire starling genome, vary with rainfall during development. Finally, I will compare patterns of DNA methylation across the genome from birds collected along an ecological gradient spanning hundreds of kilometers that varies in the degree of rainfall variability and predictability. Together, these studies demonstrate how environmental uncertainty shapes the HPA axis, allowing organisms to respond plastically to environmental change and maximize their fitness in unpredictable environments.

5-6 RUBI, TL*; KNOWLES, LL; DANTZER, B; University of Michigan; *tricia.rubi@gmail.com*
Museum epigenomics: characterizing DNA methylation across a range expansion using natural history collections
Ancient DNA researchers recently discovered that historic and ancient tissues retain *in vivo* patterns of DNA methylation, suggesting that such marks could be used to infer epigenetic variation in past populations and study how epigenetic effects change over time. We extend this approach to traditionally-prepared museum specimens. We present a novel method for characterizing genome-wide cytosine methylation at base-pair resolution (double digest RADseq combined with bisulfite treatment). We use this method to characterize methylation patterns over the course of a Great Lakes-area range expansion in the white-footed mouse (*Peromyscus leucopus*) and a non range-expanding, sympatric congener, the woodland deer mouse (*Peromyscus maniculatus*). Using specimens collected over the past 80 years, we describe spatial and temporal trends in global and locus-specific cytosine methylation. We explore these results and discuss the challenges and future directions of epigenetics research using museum specimens.

P2-105 RUBIN, AM*; WADA, H; Auburn University;
amr0101@auburn.edu
Effects of Periodic Cooling During Incubation on Heart Rate and Hatchling Morphology in Zebra Finches
The developmental environment is known to have lasting effects on phenotype and fitness. In oviparous species, the thermal environment embryos experience during incubation has been shown to strongly determine a range of traits. However, the exact mechanisms by which temperature during development influences phenotype remain largely unknown, and this is especially true for environments that experience temperature fluctuations. In birds, eggs can experience large temperature fluctuations when parents leave the nest to forage or due to weather events. Additionally, a predicted consequence of global climate change is a higher degree of climactic variation meaning less stable and consistent temperatures. To evaluate how temperature fluctuations during development may influence organism phenotype at hatch and beyond, we incubated zebra finch (*Taeniopygia guttata*) eggs under one of three conditions; one that periodically cooled eggs five times a day, one that held a constant optimum control temperature (37.4°C), and one that held a constant low temperature (36.4°C), which was the average incubator temperature of the periodically cooled eggs. Embryonic heart rate was measured at two time points during development via a Buddy digital heart rate monitor. Incubation duration, mass change during incubation, hatching success, and hatchling morphology were also recorded. We are currently analyzing the effects of periodic cooling during incubation on embryonic development, as well as morphology at hatch, in order to assess the relationship between embryonic heart rate, hatchling success, and hatchling phenotype.

95-5 RUCKER, HR*; PARKER, MR; James Madison Univ.;
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Decrypting Female Attractivity in Garter Snakes
Pheromones are utilized by many species as sexual signals driving mate choice, and pheromone production in vertebrates hinges on sex hormone action. Female red-sided garter snakes (*Thamnophis sirtalis parietalis*) produce a skin-based sex pheromone used by males for mate detection and selection. Estradiol is necessary for pheromone production, yet the specific mechanisms within the skin are unknown. Central to this is the metabolism of testosterone to estradiol via the enzyme aromatase. We hypothesize that female garter snakes synthesize estradiol locally in the skin and maintain pheromone production via tissue-specific regulation of aromatase. Further, we hypothesize that female attractiveness, and therefore pheromone production, can be inhibited by targeting aromatase activity. Using qPCR, we detected sexually dimorphic expression of aromatase in the skin (3.5-fold increase in females; t_{20}=2.30, P=0.032). To inhibit aromatase activity, we treated females with a known aromatase inhibitor (fadrozole; FAD). Females received either FAD injections (100 µg/mL; n=10 females) or control injections (saline; SHAM; n=10) three times a week for six months. Pheromones were isolated from snake shed skins, and blood plasma was collected to determine circulating estradiol. In the den the next spring in Manitoba, Canada, SHAM and FAD females were differentially attractive based on bioassays with wild males. FAD females attracted ~50% less courtship than wild females in two different bioassays (competition: $F_{2,22}$=6.54, P=0.007; mating ball test: $F_{2,24}$=22.454, P=<0.001). Collectively, our results are the first to indicate a key role for tissue-specific aromatase expression in vertebrate pheromone production.

91-7 RUDDY, BT*; PORTER, ME; Florida Atlantic University; *bruddy2018@fau.edu*

Volitional swimming kinematics of schooling blacktip sharks (Carcharhinus limbatus) in the wild

Annually, populations of blacktip sharks (*Carcharhinus limbatus*) move along the coastline, forming dense aggregations at the southern terminus of their migratory route, where shallow clear water provides a unique opportunity to study swimming kinematics of large upper trophic level predator in the wild. We quantified the undulatory kinematics during straight volitional swimming of *C. limbatus* in varying group sizes, compared kinematics of animals within an aggregation, and quantified school shape and density. We hypothesized that the presence of isotropic schooling formations and greater animal densities enables reductions in tail beat frequency (TBF), tail beat amplitude (TBA), undulatory wave form (BC), and strouhal number (St). Furthermore, we hypothesized that sharks swimming in isotropic formations will show a reduction in TBF, TBA, BC, and St as their placement within the school moved posteriorly. We used an aerial drone and motion tracking software to obtain 4K video from schools of varying sizes. Sharks in groups were tracked to determine individual swimming kinematics, school density, and the outer perimeter of the school was traced to determine school shape. Our data suggest that sharks swimming in more dense groups have a significant reduction in St and TBF compared to sharks swimming alone. Individuals positioned posteriorly in isotropic schooling formations show a significant decrease in St and TBF. A previous study showed that increased acceleration resulted in increased metabolic rates of this species. Our data suggest there may be a hydrodynamic benefit for blacktip sharks swimming in aggregations, which may impact shark energy budgets as they engage in associative behavior and maximize efficiency in long distance migration.

P1-217 RUIZ, A; California State University, San Marcos; *ruiz112@cougars.csusm.edu*

Quantifying biodiversity temporally across a 15 year period: Biodiversity varies year to year and by seasons in the San Elijo Lagoon

Wetlands are vastly important in maintaining avian diversity worldwide. Aquatic, migratory species, and species that inhabit yearly rely heavily on wetlands. Management of wetlands should take into consideration biodiversity. I examined the annual and seasonal changes to biodiversity (species richness [R] and Shannon diversity index [H']) in the San Elijo Lagoon, California over a 15 year period. I found that both species richness and Shannon diversity vary from year to year vastly. In particular, Fall and Winter H' increased positively across years ($R2 = 0.677$, $p<0.0001$ and $R2 = 0.577$, $p=0.001$, respectively). The influence of seasons on biodiversity was examined to assess which seasons expressed the highest levels of biodiversity, and species richness and Shannon diversity values were highest in Spring. Wetland use varies greatly from season to season, but overall, the relatively high Shannon diversity values over the 15 years indicate consistently high levels of species diversity and evenness throughout the wetland.

47-2 RUIZ, C*; THEOBALD, J; Florida International University; *cruiz093@fiu.edu*

Steering Responses to Motionless Stimuli in Flying Fruit Flies

Flying insects are exquisitely sensitive to optic flow, which they use to guide flight and correct perturbations from their intended course. Motion however, can be fabricated by using light adaptation or light movements over spatial and temporal patterns, producing the illusion of optic flow. We tested the responses of flying fruit flies to stimuli known to produce the sensation of motion in humans, and found quantitative differences. Illusions that are readily apparent to humans elicited no response from flies. We discuss the implications for different mechanisms underlying motion perception in walking and flying animals.

99-4 RUMMEL, AD*; SWARTZ, SM; MARSH, RL; Brown University; *andrea_rummel@brown.edu*

Regional thermal specialization in bat wing muscles: a proximal-distal temperature and thermal sensitivity gradient

As nocturnal fliers, bats must maintain a rapid wingbeat frequency in the face of thermal conditions that likely result in net heat loss from their poorly-insulated wings. Because rate-related processes in muscle slow at cooler temperatures, temperature effects in the wing muscles may impair flight performance. Bats maintain a proximal-to-distal temperature gradient during rest and activity: continuous measurements of internal muscle temperature during wind tunnel flights indicate that the distal wing muscles of *Carollia perspicillata* operate at up to 12°C below core body temperature (T_b), while the more proximal pectoralis muscle remains near T_b during flight. Thus, during normal flight, different muscles of the flight apparatus may operate at vastly different temperatures. We predicted that the contractile properties of the pectoralis would be specialized to operation near T_b, and thus more sensitive to temperature than those of the extensor carpi radialis longus (ECRL), a distal wing muscle. We previously measured the contractile properties of the ECRL in *C. perspicillata* at 22, 27, 32, and 37°C *in vitro*, and here measure the same properties over that temperature range for the pectoralis. Both muscles decline in performance below 37°C, but pectoralis performance was more sensitive to declining temperature than the ECRL for shortening velocity and several time-dependent isometric properties. Isometric force production is also highly thermally sensitive in the pectoralis. These results support our prediction that a proximal, thermally insulated muscle will be highly temperature sensitive, while a distal, thermally variable muscle will be less temperature sensitive, and suggest that endotherms compensate for temperature effects due to regional variation in body temperature.

17-7 RUPP, AE*; MOON, BR; University of Louisiana Lafayette; *arianarupp91@gmail.com*

Feeding Mechanisms and Digestive Anatomy of Mud Snakes, Farancia abacura

Feeding on elongate prey occurs in many vertebrates, including snakes. However, few publications have addressed the complexity of consuming elongate vertebrate prey. Some snakes can consume prey just as long as, and sometimes longer than, themselves, although doing so takes considerable time and effort. Mud Snakes, *Farancia abacura,* are thought to be specialist feeders on elongate prey. This diet makes Mud Snakes a useful model for understanding how snakes consume and digest large and elongate prey. Mud Snakes are widespread and abundant but secretive and difficult to find in large numbers for research, which has limited research on this species compared to other widespread snakes. We have recorded videos of Mud Snakes feeding on amphibians in order to describe and quantify the capture and consumption of elongate prey. From these video data, we have identified variation in prey handling by Mud Snakes of different size classes and on different prey items. We have also studied retention of ingested prey to determine whether or not prey size limits digestion. This research also includes the first quantitative data on feeding in hatchling Mud Snakes.

29-4 RUPPERT, KM*; BARE, EA; KLINE, RJ; RAHMAN, MS; University of Texas Rio Grande Valley; *krista.ruppert01@utrgv.edu*

Development of a New Environmental DNA Assay for Detection of the Rio Grande Siren in Highly Turbid Water

Environmental DNA (eDNA) assays have become a major aspect of amphibian surveys in the past decade. These methods are highly sensitive making them well-suited for monitoring rare and elusive species. Current efforts to study the Rio Grande siren in the Lower Rio Grande Valley (LRGV) have been hampered due to the cryptic nature of these aquatic salamanders. Arid conditions in the LRGV further add to the difficulty in studying this species, as many water bodies they inhabit are ephemeral, constraining sampling efforts to a short window after heavy deluges. Additionally, sirens are known to cease activity and reside underground when breeding ponds are dry. Conventional sampling efforts are require extensive man-hours to be effective, which is not always possible within the required sampling window. We here discuss the development of a novel eDNA assay technique for this elusive species quantified via probe-based qPCR. This study has found a small, handheld, coffee filtration apparatus to be a viable replacement for small-pore filters and bulky vacuum pumps, which are not capable of filtering the large amounts of turbid water required for siren detection. This methodology holds great promise for the assessment of Rio Grande sirens in the LRGV and for potential adaption to other south Texas amphibians also breeding in these highly turbid water bodies.

S12-12 RUSSELL, A.P.*; GAMBLE, T.; RUSSELL, Tony; Univ. of Calgary, Marquette Univ.; *arussell@ucalgary.ca*

Dissecting the evolution of the gekkotan adhesive system: one or more origins?

Gecko toe pads have been investigated for over 200 years, and interest in them has burgeoned since the turn of the millennium. Geckos are very diverse (~1700 species). About 60% of species have toe pads comprised of a hierarchy of morphological specializations involved in effecting adhesion and release. Toe pads are complex adaptations and their evolutionary history remains contentious. Since the 1950s arguments advanced advocating either a single or multiple origins of toe pads have been hampered by the poor resolution of gekkotan interrelationships. Employment of recently-constructed (from 2012 onward) robust, molecularly-based phylogenies of the Gekkota has failed to resolve the question of one or more origins of the adhesive system, largely because toe pads have been assessed as a single attribute, with scant attention being paid to their anatomical diversity. To attempt to rectify this we examine 34 features of gecko digits and investigate each using model-based ancestral state reconstruction. In this initial approach we undertake a pan-gekkotan overview to determine what, if any, broad-scale patterns exist. We find few characters common to all pad-bearing geckos, with particular features instead characterizing more restrictive clades, consistent with multiple origins of toe pads. We recognize that more refined studies within families will be needed to elucidate finer details of pattern. Exploration of this issue is important not only for understanding the evolution of the adhesive apparatus of geckos (and for what that can tell us about the evolution of complex adaptations), but also for gaining greater insights into which of its features are essential to model in biomimetic applications of its functional attributes.

S12-1 RUSSELL, Anthony P.*; STARK, Alyssa; HIGHAM, Timothy; RUSSELL, Anthony; Univ of Calgary, Canada, Villanova Univ., PA, Univ. California, Riverside, CA, .; *arussell@ucalgary.ca*

Understanding gecko adhesion: toward an integration of evolutionary, ecological biomechanical and biomimetic approaches.

The remarkable, climbing abilities of geckos have attracted the attention of biologists for over 200 years. The progress they made towards understanding gecko adhesion up to the year 2000 is reviewed. The elucidation of the molecular mechanisms of gecko adhesion catalyzed an explosion of interest in this phenomenon from 2000 onwards and resulted in the participation in gecko-inspired research of an increasing number of biologists, along with physicists, chemists, materials scientists, and engineers. Many such investigators took up the challenge of adapting the principles of gecko adhesion to the fabrication of synthetic simulacra and the applications to which these can be put. Others were stimulated to undertake field and laboratory studies to explore the evolution and field-relevant deployment of the gekkotan adhesive system, and to elucidate how it became interpolated into the mechanics of lizard locomotion. We briefly review these more recent contributions and suggest how greater interaction between various camps of investigators can potentially accelerate progress in both the understanding of the mechanisms of gecko adhesion and the application of its principles for technological advancements. The "gecko effect" provides an example of natural nanotechnology that originally arose at least 100 million years ago, and on multiple independent occasions since then. This mosaic history provides the opportunity to assess what is necessary and sufficient for its functioning. Integration between teams that study the biological system, and those who design bio-inspired synthetics will lead to a deeper level of understanding in three core areas (ecology and evolution; function, biomechanics and performance; and material science) and an invigorated impetus for the development of eco-inspired synthetics.

17-5 RUTLEDGE, KM*; SUMMERS, AP; KOLMANN, MA; University of California Los Angeles, University of Washington, George Washington University, UCLA; *kelsimarie7@g.ucla.edu*

Killing them softly: the structure and function of the jaws of a durophagous freshwater river ray (Potamotrygon leopoldi) through ontogeny

Durophagous predators consume hard-shelled prey items such as bivalves, gastropods and large crustaceans. Most of them mechanically crush heavily mineralized prey. This is expensive both from the point of view of the bite forces involved and the stresses inflicted on the predator's skeleton. It is quite common for durophagous taxa to shift from softer prey to hard prey at some point in ontogeny, implying that it is relatively harder for small animals to crush their way into prey. Batoid fishes (rays, skates, sawfishes and guitarfishes) have independently evolved durophagy multiple times, despite the challenges associated with crushing prey harder than their own cartilaginous skeleton. *Potamotrygon leopoldi* is a durophagous freshwater ray endemic to the Xingu River Basin in Brazil, with a jaw morphology superficially similar to that of distant relatives, like eagle rays (*Aetomylaeus*). We examined how the resistance to bending and mineralization of the jaws changed over ontogeny in *P. leopoldi* (n = 5, 14-45 cm disc width), using computed tomography (CT) scanning to calculate the 2nd moment of area of the jaws. *P. leopoldi* has lower jaw stiffness relative to other durophagous elasmobranchs and the skeleton nearest the jaw joints is stiffer than that beneath the dentition. While jaw stiffness has similar material distribution over ontogeny, mineralization under the teeth increases. Neonate rays have low jaw stiffness and poor mineralization, suggesting that *P. leopoldi* may not feed on hard prey early in life. These differences in the shape, stiffness and mineralization of the jaws of *P. leopoldi* compared to its distant durophagous relatives suggest there are many solutions for crushing hard prey with a soft skeleton.

S9-3 RYAN, JF*; BOBKOV, YV; BABONIS, LS; Whitney Laboratory for Marine Bioscience; *joseph.ryan@whitney.ufl.edu*

Reframing the origin of neurons

The question of whether ctenophore neurons have evolved independently has caused widespread uncertainty about the origin of nervous systems in animals. Arguments for the independent origins of animal nervous systems have centered on the absence of conserved "neural" genes and neurotransmitters in ctenophores. Here we reconsider this question by examining the developmental origin of neurons across animals. We present examples from the literature of neural cell types deriving from cell lineages that exclusively give rise to non-neural cell types in other animals. We further show that neural progenitor cells also give rise to non-neural secretory cells in numerous animal taxa. Together, these patterns reflect the labile nature of cell identity and underscore the futility of arguing for the homology of neural cell types. Rather, we advocate for the concept of a single origin of a generic secretory cell in the stem of all animals to better understand the early evolution of neurons and the potential loss of neural cell types in sponges and placozoans. Lastly, we present unpublished electrophysiology data suggesting that ctenophore neural cell types have similar electrical properties to those of cnidarians and bilaterians. Together, these ideas offer a new perspective from which to evaluate current data and outline specific experiments that could newly illuminate the evolution of neural cell types; this in turn will lead to a better understanding of animal nervous systems, including our own.

68-6 RYAN, DS*; STUTZIG, N; SIEBERT, T; WAKELING, JM; Simon Fraser University, University of Stuttgart; *dsryan@sfu.ca*

Passive and Dynamic Muscle Architecture during Transversal Loading for Gastrocnemius Medialis in Man

External forces from our environment translate to transverse loads on our muscles. Studies in rats showed that transverse loads affect muscle force in the longitudinal direction, where increases in transverse load decreased maximum longitudinal force. Changes in muscle architecture during contraction may contribute to the observed force decrease. The aim of this study was to quantify changes in pennation angle, fascicle dimensions, and muscle thickness during contraction under external transverse load. Electrical stimuli were elicited to evoke maximal force twitches in the right calf muscles in man. Trials were conducted with transverse loads of 2, 4.5, and 10 kg. An ultrasound probe was placed on the medial gastrocnemius in line with the transverse load to quantify architectural muscle characteristics during muscle twitches. Ultrasound images were enhanced and quantified using manual digitization and image transformations. Transverse loading of the muscle resulted in a decrease in the initial muscle thickness and pennation angle, with higher loads causing greater decreases. During twitches the muscle belly and fascicles transiently increased in thickness and pennation angle. The increase in muscle thickness was reduced with greater transverse load, and the increases in pennation angle and fascicle thickness were also reduced. Maximum twitch force decreased with increased transverse loads. The 2, 4.5, and 10 kg of transverse load showed a 9, 13, and 16% decrease in longitudinal muscle force, respectively. Transverse load impacts muscle deformation and contraction dynamics. This study showed that increased transverse loads caused a decrease in ankle moment, muscle thickness, pennation angle, and deformation of the fascicles.

P2-100 RYAN, TA*; TAFF, CC; ZIMMER, C; VITOUSEK, MN; Cornell University; *tar87@cornell.edu*

Relationships between weather and circulating glucose concentrations in tree swallows

The regulation and use of energy stores are important elements of coping with environmental variation. Glucose is a common molecule involved in the use and storage of energy in vertebrates. Food limitation typically causes a decrease in glucose levels; however, under acute stress, circulating glucose levels can rise through gluconeogenesis, providing energy to help survive challenging conditions. Because of the effect of weather on energy availability and foraging efficiency, weather may influence glucose regulation; however, these dynamics remain poorly understood, particularly in birds. We tested the hypothesis that baseline glucose levels would be higher in free-living tree swallows (*Tachycineta bicolor*) experiencing challenging weather conditions. Specifically, we predicted that baseline glucose levels would be positively associated with temperature, and negatively associated with windspeed under non-acute starvation conditions. We also tested the hypothesis that the rapid glucose response to acute restraint stress would be higher in birds experiencing challenging weather conditions. Specifically, we predicted that 30-mintute post-capture glucose would be negatively associated with temperature, positively associated with windspeed, and negatively associated with measures of body condition and energy reserves (high body mass, low plasma β-hydroxybutyrate). We utilize multiple timescales of weather data to understand how free-living birds respond physiologically to variation in weather --a major source of challenging environmental conditions with which organisms must cope.

14-4 RYELAND, J*; SPENCER, RJ; UMBERS, KDL; HOUSE, CM; Western Sydney University;
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Male-parental care adjustments with differing levels of paternity in a polyandrous bird

In the majority of bird species whom employ biparental care, males provide decreasing levels of care with increasing uncertainty of paternity. In the male-only parental care system, relatively uncommon in birds, providing care for young that the male has not sired, can have high detrimental effects on current additional mating's as well as on his future fecundity. It therefore follows, that if males are able to unambiguously determine paternity, then they may adjust investment in the form of parental care to match their own levels of paternity in a clutch. The Australian emu, *Dromaius novaehollandiae*, is a socially monogamous ground nesting bird, with male-only parental care. Parental care for this species is predominantly in the form of incubation, with precocial chicks requiring only protection from the father. It therefore is an ideal species for easily studying the influence of parentage on incubation behaviour in a male-only parental care species, as well as assessing whether females mate more and lay more eggs of a larger size in the nest of males who provide greater parental care. In this study we measure nest attendance and maintenance, clutch size, egg size and hatching success, to determine how these features correlate with molecular paternity. By studying what features of emu mating and nesting behaviour predict patterns of molecular parentage, we aim to better understand the trade-off between parental care and additional mating's, in a male-only parental care system.

S2-6 RYNKIEWICZ, EC*; CLERC, M; BABAYAN, S; PEDERSEN, AB; Fashion Institute of Technology, Queens Medical Research Institute, University of Glasgow, University of Edinburgh;
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Variation in Pro-Inflammatory Immune Responses Among- and Within-Individual Wild Wood Mice Impacts Parasite Infection Dynamics

The immune system is a host's main defense against infection, but how a host responds to parasites can vary between the site of infection and more systemic changes in immune phenotype. Host responses may also depend on physiological condition, demography (body condition, age, sex), and coinfection by other parasites. Such sources of variation, inherent in natural populations, can significantly impact the scale and strength of the immune response. Here we characterized how these factors drive variation in the proinflammatory response in wild wood mice, and in turn, how this variation impacts parasite infection dynamics. We longitudinally measured pro-inflammatory cytokine concentrations (TNF-alpha), immune gene expression at the local and systemic within-host scale (spleen and gut lymph nodes), and infection with the gut nematode *Heligomosomoides polygyrus* and several other coinfecting parasite species. Drug-treating individuals against gut nematodes differentially impacted inflammation in males and females at the systemic scale (spleen), and hosts of different ages varied at the local scale (gut lymph nodes). We also found that reproductively-active mice had lower local inflammation, potentially the result of competition for resources between immunity and reproduction. Measuring parasite infection dynamics of the wider parasite community revealed that variation in pro-inflammatory responses may also impact coinfecting parasites at multiple scales, with potentially significant implications for parasite spread, coinfection prevalence, and how targeted treatments may impact host condition or susceptibility to reinfection.

P3-108 SAFFOLD, C/E*; LINSER, P/J; University of Tennessee at Martin , Whitney Laboratory for Marine Bioscience ;
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The Molecular Physiology of Carbon Dioxide in the Larval Mosquito Tracheal System

The physiology of carbon dioxide elimination in the larval mosquito, a potential target for controlling the animals that cause more than 1 million deaths each year, is poorly understood. It is known that one method of carbon dioxide removal is by direct diffusion through the larva's cuticle. However, the molecular components that propagate this transcuticular diffusion are unknown. Previous study has shown that carbonic anhydrases 9 and 10, the anion exchanger AE1, and Na^+/K^+ ATPase play critical roles in pH regulation of the alimentary canal by ionizing carbon dioxide and transporting its ionic derivative, bicarbonate (Linser et al. 2009). The purpose of this study is to determine where these three molecular components are located in the tracheal system of *Aedes aegytpi* and *Culex pipiens* larvae. Paraffin sectioning, whole mount preparation, antibody labeling, confocal microscopy, and protein analysis by SDS- page western blot were used to achieve these goals. The immunohistochemical data strongly suggests that all three components are present in their predicted locations. The western blot suggests that carbonic anhydrase 9 is present in the tracheal epithelium, but its presence in the hemolymph is inconclusive. The hypothesized molecular physiology of each component is supported by the data.

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Metabolic cost of robustness: Running after losing one or two legs

After losing legs, cockroaches can still run, showing phenomenal fault tolerance. We hypothesized that this remarkable robustness is likely to increase the metabolic cost of locomotion. We tested this hypothesis for cockroaches, *Blaberus discoidalis*, running on a treadmill. We used open-flow respirometry to measure steady-state oxygen consumption at a range of speeds (2.5-12.5 cm/s) and video cameras to determine stride frequency and ground contact time. We compared cost for individuals missing one and two middle legs with intact controls. Animals maintained steady-state locomotion for at least 5 min. For all conditions, oxygen consumption and stride frequency increased with speed, whereas contact time decreased. Losing one leg increased cost by 8-30%, whereas the loss of two legs increased cost by 27-76% relative to the 6-legged condition. Middle leg loss showed no gait change, but resulted in an increase in stride frequency and a decrease in leg contact compared to intact controls. Middle leg loss destabilized animals in roll and caused animals to take more, smaller steps than intact animals to maintain the same speed. Correcting for the faster rate of force generation in animals with reduced leg number by calculating the cost per stride resulted in no significant differences, but animals with two middle legs missing did show significantly greater ground contact costs. Cockroaches exhibit fault tolerance, but at a metabolic cost.

121-1 SALINAS, S*; GOLDEN, SQ; SCHERTZING, CL; IRVINE, SE; MUNCH, SB; Kalamazoo College, National Marine Fisheries Service; *santiago.salinas@kzoo.edu*

Variation at Extreme Thermal Environments Under Constant and Fluctuating Temperatures

Climate change is increasingly exposing populations to rare and novel environmental conditions. Theory suggests that extreme conditions will expose ‘hidden' phenotypes, with a concomitant increase in trait variation. Although some empirical support for this exists, it is also well established that physiological mechanisms change when organisms are exposed to constant vs. fluctuating temperatures (most experiments to date have been conducted under constant conditions). To determine the effect of normal, rare, and novel temperatures on the release of hidden variation, we exposed fathead minnows, *Pimephales promelas*, to five fluctuating and four constant temperature regimes. We then measured each individual's length-at-age (weekly over 60 days), critical thermal maximum, 5 morphometric traits, and fluctuating asymmetry. Length-at-age for both constant and fluctuating conditions decreased with temperature, and variance decreased with temperature under fluctuating conditions but increased and then decreased in constant temperatures. CT_{max} in both treatments increased with increasing water temperature, while variance decreased in warmer waters. No consistent pattern in mean or variance was found across morphometric traits or fluctuating asymmetry. Our results suggest that variance can decrease as the environment becomes more stressful, so it may be difficult to establish comprehensive rules for the effects of rarer environments on trait variation.

46-7 SANDES DE SOUZA, AP*; SMITH, NM; WILSON, RS; University of Brasilia, Brazil, University of Sydney, Australia, University of Queensland, Australia; *r.wilson@uq.edu.au*

Predicting success in physical activities: combining studies of sport and animal performance to enhance both disciplines

Just as biologists seek to link phenotypes to fitness, sports scientists try to identify the traits that determine athlete success. Both disciplines would benefit from collaborations, but few of the tools used in one field are used to advance the other. In this study, we used an analytical approach common in evolutionary biology to isolate traits associated with success in a specific sporting activity - soccer performance. We also used a deconstructive approach common in sports science that could offer new insights into the study of physical performance and its influence on adaptation in nature. Specifically, we quantified the sprinting, dribbling, passing, and control performance of 30 elite Brazilian junior footballers, and showed which traits were associated with success in a custom-designed small-sided soccer game (3 attackers vs 1 defender). Practically, our study identifies a clear set of performance traits that can be used to identify talented midfield soccer players. In addition, our data show the benefits of deconstructing a highly complex team-sport into smaller sub-activities that can be more easily studied, an approach that could be beneficial for studying animal performance in nature.

P3-29 SANDES DE SOUZA, AP*; SMITH, NS; WILSON, RS; University of Brasilia, Brazil, University of Sydney, Australia, University of Queensland, Australia; *r.wilson@uq.edu.au*

Testing a model of escape performance in terrestrial animals

Once prey is detected, survival depends on out-running, out-manoeuvring, or fighting off the predator. Though predation attempts involve at least two individuals—namely, a predator and its prey—studies of escape performance typically measure a single trait (e.g. sprint speed) in the prey species only. Recently, a theoretical model of escape success was developed that is based on the relative performance of prey versus predator with regards to their acceleration, top speed, agility and deceleration. The model suggests acceleration, top speed, and agility are all important determinants of running performance along curved paths, and that prey with higher agilities should exploit their higher performances along curved paths to outrun predators. This model is based on the premise that the relative importance of acceleration, top speed and agility changes with increasing path curviness. Here, we test this mathematical model using analyses of human performance when running along paths of varied curvature.

26-2 SANDFOSS, MR*; LILLYWHITE, HB; Univ. of Florida, Dept. of Biology; *mrsandfo@ufl.edu*

Water relations of an insular population of Florida cottonmouth snakes, Agkistrodon conanti.

Seahorse Key (SHK) is a continental island near coastal Florida that lacks permanent sources of fresh water and is inhabited by a large population of Florida Cottonmouth snakes, *Agkistrodon conanti*. Because cottonmouths on the mainland are strongly associated with freshwater habitats, conspecifics on SHK likely have developed alternative strategies for maintaining water balance. We used a mix of field and laboratory experiments to investigate the possible stresses and adaptations related to dehydration within the cottonmouth population on SHK. Our objectives were to 1) measure the hydration status of free-ranging snakes on SHK in relation to rainfall patterns, 2) compare the drinking threshold of cottonmouths from island and mainland populations and 3) compare seawater (SW) drinking behavior of island and mainland snakes when in a dehydrated state. We predicted cottonmouths on SHK are using rainfall to maintain water balance, and that SHK and mainland snakes would differ in their dehydration tolerance and seawater drinking behavior. Our results show 1) cottonmouths captured on SHK were more likely to be in a dehydrated state as time increased since last rainfall, 2) snakes from SHK and mainland populations showed no difference in drinking threshold and 3) cottonmouths from island populations avoided drinking high salinity water (>15% SW) while mainland snakes showed no preference. Overall, these results support the hypothesis that populations of cottonmouths inhabiting islands have developed behavioral and physiological adaptations to survive within this novel habitat.

133-3 SANDMEIER, FC*; LEONARD, KL; TRACY, CR; DRAKE, KK; ESQUE, T; NUSSEAR, K; GERMANO , J; Colorado State University-Pueblo, University of Nevada, Reno, US Geological Survey, University of Nevada, Reno, Department of Conservation, New Zealand; *fcsandmeier@gmail.com*

Tools to understand seasonality in health: quantification of microbe loads and analyses of compositional ecoimmunological data reveal complex patterns in tortoise populations

Using data from six wild tortoise (*Gopherus agassizii*) populations, we quantified seasonal differences in basic immune system measurements and microbial load in the respiratory tract, pertinent to this species' susceptibility to disease. We used multivariate analyses of immune measures to detect trends in temporal and spatial variation in immune function. We stress the importance of using centered log-ratio (clr) transformations of leukocyte counts as necessary for the correct analysis of compositional data. Lymphocytes numbers increased and decreased temporally in opposition to cells involved in innate inflammatory processes (heterophils and eosinophils). We created a quantitative PCR assay for the potential pathogen, *Pasteurella testudinis*, and tested animals for *P. testudinis*, as well as for the known respiratory pathogens *Mycoplasma agassizii* and *M. testudineum*. We found very little disease and suggest that *P. testudinis* is a prevalent, commensal microbe in these tortoise populations. We determined that analysis of *P. testudinis* loads is a tool to study natural fluctuations in microbe levels in tortoise respiratory tracts. Our analyses showed that both the potential for inflammatory responses and microbe levels are highest in the spring for healthy tortoises. The genetic and statistical tools we used are easily applicable to other wildlife systems and provide the necessary data to quantify species-wide trends in health and test hypotheses pertinent to host-microbe dynamics.

P3-97 SANDOVAL HERRERA, NI*; WELCH , KC; University of Toronto; *natalia.sandovalherrera@mail.utoronto.ca*

Sublethal Effects of Neurotoxic Pesticides on Bats: from Cells to Behavior

Agricultural intensification and the consequent increase of pesticide use has been considered a major threat for bat populations in Europe. However, no research on this topic has been conducted in tropical agrosystems, where most of the arable land is frequently treated with pesticides, particularly large monoculture plantations like banana and pineapple. Considering that bats can eat more than 90% of their body mass every night, species that forage preferentially in crops could be highly exposed to pesticides through their prey. This study seeks to determine the sublethal effects of organophosphate pesticides on bat species foraging in or near crops. Organophosphate pesticides are commonly used neurotoxic chemicals that can impair vital functions such as the ability to feed, escape predation or reproduce. In order to assess the risk of exposure, we have studied foraging activity of bats in crops in Belize, Mexico and Costa Rica, countries known for their great bat diversity and extensive use of pesticides. To estimate intake by bats, we will analyze pesticide levels in insects collected in the same locations. Subsequently we will use an integrative approach to study the toxic effects of organophosphates on captive and wild bats. This approach involves measuring molecular (enzyme activity), physiological (metabolic rate, immune response) and behavioral (echolocation) biomarkers, aiming to extrapolate these responses across levels of biological organization. Understanding the mechanisms and effects at different scales will enable to better predict the implications on populations and communities and help to inform mitigation strategies.

P3-99 SANDOVAL-HERRERA, N*; ENGLISH, SG; BISHOP, CA; ELLIOTT, JE; WELCH, KC; University of Toronto, Environment and Climate Change Canada, Environment and Climate Change Canada; *simon.english@mail.utoronto.ca*

Effects of neonicotinoid insecticides on hummingbirds

Neonicotinoids are neurotoxic systemic insecticides that have become the most widely used group of insecticides worldwide. These compounds affect the nervous system, interfering with the transmission of nerve impulses and impairing vital physiological processes. There is a growing concern about their environmental impacts, particularly linked to bee colony collapse disorder and drastic reductions in insect populations. While the loss of pollination services provided by bees to ecosystems and agriculture has been widely studied, the neonicotinoid effects in other pollinators such as hummingbirds haven't been assessed yet. Hummingbirds in particular present a great risk of exposure to pesticides due to their high daily nectar intake, making them also more vulnerable to the adverse effects of these toxic substances. We examined the sublethal toxic effects of the neonicotinoid imidacloprid in captive Ruby-throated hummingbirds (Archilochus colubris). Using a multibiomarker approach we evaluated biochemical, physiological and behavioral impairments. Two doses were tested, a high dose based on previous toxicity assessments in similar size species and a low dose calculated from the potential daily consumption of imidacloprid by hummingbirds feeding in blueberry crops. To determine cellular neurotoxic effects, Cholinesterase activity and oxidative stress response were measured. As physiological response Resting Metabolic Rate and immune function were examined. Likewise, the toxicokinetics of the insecticide were assessed through urine analyses. This is the first study assessing the effect of pesticides in hummingbirds, our results will provide insights of pesticide exposure as a potential threat for populations of these species and will help management agencies improve regulation.

70-2 SANGER, TJ*; CZESNY, B; HARDING, L; DHINDSA, S; Loyola University Chicago; *tsanger@luc.edu*

Normal and abnormal craniofacial morphogenesis in the lizard Anolis sagrei

Understanding normal craniofacial morphogenesis in a wide range of vertebrates will shed light on whether similar or distinct processes are modified to generate the remarkable diversity in adult form. Understanding the developmental bases of craniofacial malformations will shed further light on potentially sensitive developmental process that are most easily affected by genetic and environmental perturbations. To date, the embryology and molecular regulation of craniofacial development has not been examined in squamates, lizards and snakes. Using a battery of imaging techniques-uCT scanning, fluorescent in situ, and electron microscopy-we have investigated craniofacial morphogenesis in the lizard, *Anolis sagrei*. Compared to more commonly studied species, chickens and mice, we observe a unique shape to the craniofacial prominences. The expression of key patterning molecules, Shh, Fgf8, and Bmp4, parallels this unique morphology. We have not observed a distinct frontal ectodermal zone. We previously reported an increased rate of craniofacial malformations in lizard embryos that experienced thermal stress. We have further narrowed this window to the period of facial morphogenesis, during the peak period of cell proliferation and facial prominence outgrowth. Increases in the severity or duration of the thermal insult generate more severe craniofacial malformations. Our preliminary data suggest that these malformations are the result of disrupted Shh signaling. Together these results increase our understanding of the molecular regulation of vertebrate craniofacial development and on a thermally sensitive processes of craniofacial development that may be common among vertebrates.

S7-2 SANTANA, SE*; ARBOUR, JH; CURTIS, AA; STANCHAK, KE; Univ of Washington; *ssantana@uw.edu*
Integrating Traditional and Modern Approaches to Study Morphological Evolution in Bats: Where Is The Point of Diminishing Returns?
The fields of comparative morphology and evolutionary biology have undergone a modern renaissance due to increased accessibility to powerful computational and imaging methods. These have allowed more accurate documentation, measurement and modeling of morphological complexes across an unprecedented spectrum of species, and more rigorous tests of evolutionary hypotheses. Comparative morphologists and biomechanists have particularly benefited from X-ray Computed Tomography (CT) and diffusible iodine-based contrast enhanced CT (diceCT), a suite of imaging techniques that allow the observation and measurement of small and/or otherwise inaccessible anatomical structures, and the creation of highly accurate three-dimensional renditions for biomechanical modeling. But, do the larger datasets generated through these methods always confer greater power to test hypotheses when compared with more traditional methodologies? And, where is the point of diminishing returns when using these tools? Here, we contrast the advantages and difficulties of using data-rich CT methods versus traditional approaches in the study of skull and jaw adductor anatomy, function, and macroevolution in bats. We also show how modern imaging tools can, and sometimes should be, integrated with traditional approaches (e.g., dissections) to quantitatively study muscle function and evolution. By contrasting traditional and modern tools, we illustrate how and when small data may be preferable over big data, and vice versa, and how different methodologies can complement each other in comparative analyses of morphology and function.

P2-229 SANTYMIRE, RM*; WALLACE, SC; Lincoln Park Zoo, East Tennessee State University; *rsantymire@lpzoo.org*
Has post-bottleneck inbreeding reshaped the baculum in the black-footed ferret?
In the mid-1980's, the last remaining black-footed ferrets (Carnivora: Mustelidae: *Mustela nigripes*), an obligate carnivore that feeds on prairie dogs throughout North America's Great Plains, were removed from the wild to initiate a captive breeding program to save the species from extinction. After more than 30 years of captive breeding (starting with 7 founders), the rate of reproductive failure has increased from 20-30%, to nearly 70%. This reduction could be attributed to declining semen quality in males and/or the increased rate of ovulation failures in females. Moreover, because the baculum plays an important role in semen deposition and the degree of stimulation of the female reproductive tract (induced ovulation), its morphology provides information on male quality and female mate choice. Consequently, we wanted to determine if the baculum shape and size had changed over the duration of the breeding program, thereby potentially influencing reproductive success. Hence, we measured 50 bacula from captive adult ferrets born between 1993 and 2007, and obtained siring histories (studbook records) and semen data from 27 of these males. With no novel genes to bring into the population (naturally), inbreeding coefficients (F) will continue to increase over the years. Not surprisingly, we found that as the male F increased, the number of kits sired declined. Ferret body length was not related to baculum size and shape. However, we found that the baculum base width declined over time, while baculum length remained the same. The thinning baculum base was not directly linked to reproductive success in these males. Next steps are to continue measuring bacula from historic and modern specimens as a comparison between wild and captive born ferrets to further explore the role of the captive environment on the baculum morphology.

P2-112 SANTYMIRE, RM*; SACERDOTE-VELAT, AB; GYGLI, A; KEINATH, DA; POO, S; HINKSON, KM; MACK-MCKEAG, EM; Lincoln Park Zoo, The Chicago Academy of Sciences, US Fish and Wildlife Service , US Fish and Wildlife Service , Memphis Zoo; *rsantymire@lpzoo.org*
Investigating the stress physiology of Wyoming toads (Anaxyrus baxteri) using dermal cortisol analysis among various environmental conditions
Amphibian populations are declining worldwide, and increased exposure to environmental stressors, including diseases like *Batrachochytrium dendrobatidis*, has been proposed as one reason for these declines. Our goal was to use a novel, noninvasive dermal swabbing method to measure glucocorticoids and investigate the relationship among disease, environmental conditions and stress physiology in the critically endangered Wyoming toad. Our objectives were to validate the use of dermal swabs to measure cortisol using an adrenocorticotropic hormone (ACTH) challenge on 8 captive Wyoming toads (4 ACTH: 2M, 2F and 4 saline as a control: 2M, 2F); 2) compare fecal glucocorticoid metabolites (FGMs) pre- and post-ACTH experiment; and 3) investigate stress physiology of toads across three different reintroduction sites with varying population success and disease prevalence. Results validated the use of dermal swabs cortisol peaking immediately after the ACTH injection, while saline remained consistent over time (up to 2 hours). FGMs were elevated on Day 1 post-ACTH for the male and Days 2-4 for the female compared to FGMs before the experiment. Saline-injected toads had no change in FGM over time. Dermal cortisol was similar across one reintroduction site compared to captive toads. We also collected additional samples to compare habitat type and disease prevalence across two other sites. Dermal hormonal analysis is a novel tool that can be used to study amphibian stress physiology and can provide information on how environmental conditions are impacting population success.

P1-216 SARKIS, C*; SENEY, EE; FORSMAN, AM; University of Central Florida; *anna.forsman@ucf.edu*
Optimizing NextGen DNA Metabarcoding Methods for Characterizing the Diet of Free-Living Sea Turtles
Sea turtles consume both plant and animal prey and there is significant variation in diet composition among species and life stages. Visual inspection of gut contents is an effective but very time-consuming approach, which becomes increasingly difficult with digestive breakdown. Therefore, the objective of our current work is to optimize and validate the use of DNA metabarcoding techniques for characterizing sea turtle diet alongside visual inspections. Here we present results from testing multiple metabarcoding primer pairs with diet samples collected from turtles stranded off the coast of Florida. We tested a panel of animal- and plant-specific primer pairs, targeting multiple genomic regions (e.g., CO1, 18S, TrnL), for effective PCR amplification. Our goal was to maximize diversity of diet items detectable by Illumina sequencing of amplicon libraries. Although metabarcoding primers are referred to as being universal, each primer pair will have biases against certain taxa. Thus, it is critical to establish an appropriate suite of primers to capture the best representation of true diet composition. Results from this work contribute rigorous methods and critical baseline data to inform our ongoing studies of sea turtle diet in the context of life history, ecology, and disease dynamics.

73-4 SASSON, D/A*; JOCSON, D; FOWLER-FINN, KD; Saint Louis University, Washington State University; *daniel.sasson@slu.edu*

The thermal sensitivity and quantitative genetics of mate attraction signals and preferences in the treehopper, Enchenopa binotata

The treehopper *Enchenopa binotata* uses substrate-borne vibrational signals that travel through the plant stem for sexual communication. Males produce mate attraction signals to which females respond—if those signals match their preferred frequency (Hz)—to initiate pair formation. Treehoppers live in thermally variable environments, and nothing is known about how their signals and preferences may change with temperature, and nor whether genetic variation in responses to temperature exist. Here, we tested for the thermal sensitivity and heritability of signal traits and preferences using a full-sib, split-brood quantitative genetics design. Using a vibrational playback experiment, we tested the frequency of male signals and female peak preference across five ecologically relevant temperatures (21 - 33° C). We then calculated the heritability of 1) signal frequency (males) and preference (females), and 2) the signal and preference thermal reaction norms. We found that both male signals and female preference positively correlate with temperature, but only male signals were significantly heritable. We also found no significant genetic variation in the thermal reaction norms (i.e. no gene by environment interaction) for either male signals or female preferences. Overall, while treehopper signals and preference are thermally plastic, the lack of variation in thermal sensitivity between signals and preferences, and lack of variation across genotypes, suggests that mate-pair formation should not be disrupted by changes in temperature.

67-7 SATHE, EA*; CHRONISTER, NJ; DUDLEY, R; Univ. of California, Berkeley; *eksathe@berkeley.edu*

Incipient Wing-Flapping Enhances Aerial Performance in a Robotic Glider

Fossils intermediate to theropod dinosaurs and modern birds show well-developed flight feathers on both fore- and hindlimbs that indicate aerodynamic function. To test the biomechanical functionality of these transitional structures, we evaluated flight performance of a robotic model with forewings of two sizes activated over a range of wing flapping kinematics. The robot was launched at fixed height via catapult with the wings either held in fixed position laterally, or when flapping at different combinations of three wingbeat frequencies and three stroke amplitudes. Wing length, for all frequency-amplitude combinations, was the most important parameter in determining horizontal distance travelled and total time aloft. Wingbeat frequency and stroke amplitude contributed positively and equivalently to horizontal distance and total time aloft, when compared to fixed-wing gliding. Rudimentary wing flapping at low frequencies and amplitudes thus improves aerodynamic performance for gliders at physical scales relevant to the origins of vertebrate flight. In combination with recent paleontological findings of four-winged avian precursors, these results further buttress the hypothesis of an aerial origin for flapping flight in birds.

P2-77 SATTERLIE, R; University of North Carolina Wilmington; *satterlier@uncw.edu*

Buccal Cone Structure and Prey Acquisition in the Pteropod Mollusk Clione limacina

The pteropod mollusk *Clione limacina* is a feeding specialist, only consuming shelled pteropods. As a result *Clione* use the hydraulic eversion of six tentacle-like buccal cones to catch the actively swimming prey. The surface of the buccal cones is covered with adhesive papillae that possess terminal packets of electron dense granules. At the base of the epithelium is a thin layer of circular, smooth muscle, which is presumably used to help extend the buccal cones. Medial to the circular muscle are two layers of longitudinal muscle. The outer layer is made up of bundles of smooth muscle cells, and is equally distributed around the buccal cones in a sub-epithelial position. This layer functions as retractor muscles for returning the deflated buccal cones into the mouth. The other, more medial layer of longitudinal muscle is comprised of larger bundles of striated muscle, which are concentrated on the oral side of the buccal cones. These muscle bundles are used for the closure of the everted buccal cones on the prey, and presumably for prey manipulation, which rotates the prey until the shell opening is over *Clione's* mouth. Once the prey is gripped by the radula and oral hooks, the buccal cones are partially or fully retracted. The radula and hooks are then used to pull the prey tissue, intact, from the shell.

43-2 SAVAGE, AE*; TRUJILLO, A; HOFFMAN, EA; SAVAGE, Anna; University of Central Florida; *anna.savage@ucf.edu*

Spatiotemporal phylogeography of immune genes in the frog-fungus disease system

Immune gene diversity is linked to disease susceptibility in a wide variety of animal taxa, particularly relationships between Major Histocompatibility Complex (MHC) polymorphism in vertebrates and resistance to specific pathogens. While MHC polymorphism is a significant predictor of chytridiomycosis susceptibility across vertebrate taxa, we lack a spatiotemporal understanding of how immune gene diversity and disease pressure have interacted to shape population persistence. In amphibians, the fungal disease chytridiomycosis has caused the decline or extinction of hundreds of species, prompting numerous genetic and immunogenetic investigations into disease susceptibility. Here, we use the widespread North American frog *Rana pipiens* and compare mitochondrial and MHC diversity over space (continent-wide) and time (1970s-present) to identify whether phylogeographic patterns of diversity and population stability are consistent with MHC-based functional genetic diversity. Additionally, we compare MHC allelic diversity across Rana pipiens populations to MHC diversity in other anuran taxa, and test whether populations that are declining in the western USA have reduced immunogenetic diversity or lack known protective MHC alleles and supertypes. Ultimately, we aim to understand how frogs are responding to disease on a broad spatial scale by resolving whether immunogenetic adaptation is a central driver of population persistence or if neutral demography dictates evolutionary trajectories.

S3-5 SAWICKI, GS*; ABBOTT, E; NEWZEK, T; PATEK, S; WALL, C; SCHMITT, D; Georgia Institute of Technology; *gregory.sawicki@me.gatech.edu*

Exploring the Limits of Muscle-based Latch Systems for Power Amplification

Animals can amplify the mechanical power output of their muscles as they jump to escape predators or strike to capture prey. One mechanism for amplification involves muscle-tendon (MT) systems in which a spring element is pre-stretched while held in place by a ‘latch' that prevents immediate transmission of muscle power to the load. In principle, this storage phase is followed by a triggered release of the ‘latch', and elastic energy released from the spring element enables muscle to exceed its maximum power limit (Pamp=Pmt/Pmax muscle >1.0). Latches enable power amplification by increasing the muscle work generated during storage and reducing the duration over which that stored energy is released to power a movement. Previously described biological ‘latches' include: skeletal levers, anatomical triggers, accessory appendages and even antagonist muscles. In fact, many species that rely on high-powered movements also have a large number of muscles arranged in antagonist pairs. Here, we examine whether antagonist muscles can be useful as active latches to achieve controlled power amplification. We developed a computer model of a frog hindlimb driven by a compliant MT. We simulated MT power generated against an inertial load in the presence of an antagonist muscle ‘latch' (AML) with relaxation time varying from very fast (10ms) to very slow (1000ms). The fastest AML produced power amplification (Pamp =5.0) while the slowest AML produced power attenuation (Pamp =0.43). Notably, AMLs with relaxation times shorter than ~300ms also yielded greater power amplification (Pamp >1.20) than the system driving the same inertial load using only an agonist MT without any AML. Thus, animals that utilize a sufficiently fast relaxing AML ought to be capable of achieving greater power output than systems confined to a single agonist MT tuned for maximum Pamp against the same load.

S11-9 SAXENA, Aditya; SHARMA, Virag; GUTIERREZ, Haydee; ERBERICH, Joel; TAN, Fayth; ELLIS, Caroline; HILLER, Michael; COOPER, Kimberly*; UC San Diego, Max Planck Institute, Dresden, University of California, San Diego; *kcooper@ucsd.edu*

What Big Feet You Have! Scaling Skeletal Proportion During Development and Evolution

Our long arm bones allow us to reach for objects that our short fingers grasp and manipulate with remarkable dexterity. Since skeletal proportion is integral to vertebrate animal form and function, the variety of limb proportions is also a striking aspect of species diversity. However, little is known of the molecular mechanisms that determine the different lengths of individual limb bones in any species. Here, we leverage the extreme hindlimb proportion of the bipedal jerboa (*Jaculus jaculus*) and its close evolutionary relationship to the laboratory mouse (*Mus musculus*) to identify genes that underlie differential skeletal growth. Although expression levels diverged throughout the genome over approximately 55 million years since the last common ancestor of the two species, differences at only 10% of orthologous genes are associated with the skeletal growth rate differences that contribute to limb proportion. These include genes that are expressed in multiple growth plates, which may be locally tuned by modular enhancers, and genes with more regionally restricted expression. Most of these genes had no known growth plate function, even though many are developmental transcription factors or are associated in other tissues with signaling networks that are critical regulators of skeletal elongation. We show that two of these, a retinoic acid antagonist and a BMP signaling inhibitor, are sufficient to modulate skeletal growth. Together, these findings suggest that the evolutionarily increased growth rate of the jerboa foot occurred in part by releasing growth potential that is restricted in mouse metatarsals.

P2-145 SAYAVONG, N*; GUNDERSON, AR; STILLMAN, JH; TSUKIMURA, B; California State University, Fresno, Tulane University, San Francisco State University; *sayavongnathan@gmail.com*

Effects of interspecific interactions, increased population density, and thermal stress on vitellogenesis on intertidal crabs Petrolisthes cinctipes and P. manimaculus.

Increased temperatures from global warming can lead to lethal temperatures for the intertidal crab *Petrolisthes cinctipes* (Decapoda: Anomura). Physiological stress from increased temperature may force redistribution into cooler environments (Stillman and Somero 1996). As a result, interspecific interactions and increased population density may occur that threaten the fitness of its congener, *P. manimaculus*, through behavioral encounters. To investigate the effects of interspecific interactions, increased population density, and thermal stress, *P. cinctipes* and *P. manimaculus* were collected from November 2017 through July 2018 and exposed to thermal stress and placed at high and low densities with conspecifics and congeners. Hemolymph samples were taken from each crab before and after density and thermal stress treatments. To quantify the effects of treatments, an ELISA was used to quantify Vg levels in hemolymph before and after treatment (Delmanowski et al. 2017). During summer months, *P. cinctipes* showed decreased vitellogenesis, likely due to annual thermal stress (Salas 2017). Increased interspecific and intraspecific species interactions in high densities with thermal stress impaired vitellogenesis in *P. manimaculus*. At low densities vitellogenesis in *P. manimaculus* increased. These data suggest that the relocation of *P. cinctipes* into the lower intertidal can cause interspecific species interactions that are stressful for *P. manimaculus* at high densities. Thus, an increase in thermal stress to *P. cinctipes* that causes a migration into *P. manimaculus* habitat, can also cause a decline in the latter's reproductive output.

P1-295 SCHAALE, LE*; BAXLEY, JB; PRICOPE, NG; DANNER, RM; Univ. of North Carolina, Wilmington; *Les6953@uncw.edu*

Viewing habitat through another lens: Bird nest-site selection and productivity across the beach thermal landscape

Little is known about the fine-scale temperature variations of the coastal landscape, which limits our ability to assess its effect on animal productivity. In 2018, we studied the effects of the thermal landscape on the least tern (*Sternula antillarum*), in a breeding colony on Lea-Hutaff Island, NC. Our three hypotheses are: (1) the thermal landscape, as measured by thermal imaging, will be highly variable and will reflect ambient environmental conditions. (2) The thermal landscape, as measured from thermal images, influences nest-site selection by least terns. Specifically, we predict that birds avoid nesting in the hottest locations. (3) The thermal landscape, as measured from thermal images, limits nest success for least terns. We predict lower nest success for nests in the hottest locations. We monitored 157 nests. Nest success was determined by successful hatching of chicks. We recorded surface temperatures via a fixed-wing mapping unoccupied aerial vehicle (UAV). We launched the UAV ~250 m away from the colony and maintained an altitude of 122 m to minimize bird disturbance. The UAV carried a thermoMAP thermal camera with a temperature resolution of 0.1˚C. At the study location, we recorded ambient environmental conditions at ground-level throughout the season. The weather data will help determine which variables influence sand surface temperature and explore the cause of nest success. Our preliminary results indicate that there is a wide range of temperatures across the landscape, supporting hypothesis 1. Tern nest locations varied in surface temperature. Nest success decreased in nests incubated in hotter locations and during a weeklong heat wave, providing tentative support for hypothesis 3.

P1-241 SCHAMMEL, KS*; MOOI, R; ARMSTRONG, AF; Pomona College, Claremont, CA, California Academy of Sciences, San Francisco, CA; *kssh2015@mymail.pomona.edu*

Applying molecular data to problems in sand dollar phylogeny (Echinodermata: Clypeasteroida)

The Clypeasteroida (sand dollars and sea biscuits) is among the most easily recognized of irregular (burrowing) echinoid groups. These animals are of increasing interest due to their excellent fossil record, and for their ecological responses to climate change over geologic time. Morphological phylogenies of clypeasteroids and their closest relatives, an informal group known as "cassiduloids" (lamp urchins), have questioned clypeasteroid monophyly -- a clade supported by many morphological features. Recent molecular trees suggest that some features have evolved more than once. For example, most urchins have an Aristotle's lantern, a five-part jaw apparatus used in morphological analyses. Outgroups of Clypeasteroida, including "cassiduloids" and heart urchins (Spatangoida and Holasteroida), lack a lantern as adults. Distantly related "regular" urchins and clypeasteroids have a lantern, suggesting that it reappeared in a monophyletic Clypeasteroida. The molecular work suggests reacquisition of the lantern separately in sea biscuits and sand dollars. A weakness in those analyses has been the lack of a focus on clypeasteroids, usually because of inadequate taxon sampling. We address this using Sanger sequencing methods on a set of key clypeasteroids and "cassiduloids". Several other problems, such as the phylogenetic position of miniaturized, bean-shaped clypeasteroids such as fibulariellids with the bizarre, but otherwise sand dollar-like rotulids, are also explored. Problems with, and possible solutions for resolving the phylogeny are discussed in view of differing evolutionary rates and geologic depth of nodes implied by our phylogenetic results.

112-4 SCHATZ, A*; MCDOWELL , J; RIVEST, EB; Virginia Institute of Marine Science, William & Mary; *kschatz@vims.edu*

Physiological mechanisms of carry-over effects due to environmental salinity experience of Crassostrea virginica larvae

Because oysters can experience varied environmental salinity regimes between life stages, performance of juveniles and adults may be impacted by carry-over effects. Carry-over effects are potential mechanisms of acclimatization: adjustments that allow an individual to sustain physiological function across changing environmental conditions during its lifetime. Larval development under different salinity regimes requires varied amounts of osmoregulation, a basal metabolic process, causing shifts in energy budget allocation that may impact juvenile physiology, and conceivably stress tolerance, making this an important area of focus. Oyster larvae from a commercial oyster hatchery were exposed to three different salinities (13, 15, and ambient salinity at the commercial hatchery) from two days post-fertilization. Juveniles from each larval treatment were then placed in two Chesapeake Bay tributaries of differing salinity regimes. Temperature, salinity, dissolved oxygen, pH, and total alkalinity experienced during larval and juvenile phases were documented. To detect physiological mechanisms of carry-over effects, growth, total lipid, total protein, total antioxidant, and ratio of glutathione to glutathione disulfide were measured in both larval and juvenile stages. Larvae under the lowest salinity had faster growth, and assessments of juvenile performance show whether this success translates into better growth and stress tolerance under different environmental conditions. Studying how larval environmental experience might carry-over to effect juvenile performance will further understanding of potential acclimatization strategies for this species with future environmental change.

P2-201 SCHERR, MP*; BADE, LM; ANGELINI, DR; Colby College; *mscherr@colby.edu*

Microbiome analysis of gut contents from the cownose ray, Rhinoptera bonasus, a species with a complex history of synanthropy

Cownose rays, *Rhinoptera bonasus*, are migratory cartilaginous fish native to the western Atlantic. This species migratory patterns can bring it into conflict with humans. While their feeding ecology is not well defined, they are known to feed on mollusks and crustaceans. Current high-throughput sequencing technology offers the potential to gain more insight into the feeding ecology and the potential for impact of these rays on aquaculture. We apply this novel approach with an analysis of the contents and microbiome composition of these marine vertebrates. Cownose rays collected from Chesapeake Bay, Virginia and off the coast of North Carolina were dissected, and DNA samples were isolated from multiple prey items within the stomach and spiral valve. These samples were sequenced for the *16S* ribosomal RNA gene in order to determine bacterial composition. The barcode region of *cytochrome oxidase subunit I (COI)* was also sequenced for identification of prey species. Gut microbial communities were highly diverse. Microbial composition was found to differ significantly by age, capture location, and time of year.

6-7 SCHIAVON, L; BATTISTOTTI, A; MARINO, IAM; DULIERE, V; CODOGNO, G; BEONI, S; DAL BORGO, L; DE BIASIO, L; SOAVE, N; LA MESA, M; ZANE, L; PAPETTI, C*; University of Padova, Italy, Royal Belgian Institute of Natural Sciences, Brussels, Belgium, Istituto di Scienze Marine (ISMAR), Consiglio Nazionale delle Ricerche, Ancona, Italy; *chiara.papetti@unipd.it*

In Cold Blood: Speciation, Introgression and Hybridization in Antarctic Fish

Correct species identification is essential to assess biodiversity and species richness in ecosystems threatened by environmental changes such as in the warming Antarctic waters. Recent findings suggest we have just begun to appreciate how complex is the notothenioid radiation and species identification. This study aims to expand our knowledge about the two notothenioid genera *Chionodraco* and *Lepidonotothen*. By means of population genetics and otolith shape analyses, we intend to ascertain whether and how extensive is the interspecific gene exchange within genera, how many species they include and what species are taking part in the system. By means of a Lagrangian modelling approach, we want to test hypothesis about possible routes of dispersal of Antarctic fish species and what is the geographic scale of the interspecific exchange. So far, genetic results indicate that hybridization occurs among species within the two genera although not extensive enough to prevent species diversification, while otolith morphology analysis enables the approximate separation of species-specific clusters. Oceanographic patterns suggest alternative routes of dispersal that could support the transport of larval stages. Ecological barriers to interspecific reproduction could constrain the impact of hybridization in sympatric *Chionodraco* and *Lepidonotothen* species. This study is expected to contribute an overall picture of the two genera in terms of distribution and genetic structure, providing tools and protocols to assist the identification of species and hybrids as a valuable resource also for other Antarctic notothenioid species.

41-6 SCHIEBEL, PE*; RIESER, JM; ASTLEY, HC; HUBBARD, AM; DIAZ, K; GOLDMAN, DI; Georgia Institute of Technology; *perrin.schiebel@gatech.edu*

Mechanics of Snake Slithering on Deformable Substrates.

Elongate, limbless animals from the microscopic *C. elegans* to eels and snakes move in both fluid and terrestrial habitats using flexural waves of the body. Swimming in fluids is well-understood and dependent on the speed and size of the locomotor and the properties of the media. However, little is known about undulatory motion in materials like mud, rotting flora, and granular matter (GM) where the surroundings provide propulsion while yielding but, unlike fluids, may be permanently deformed by the interaction. We begin the search for principles by studying lateral undulation on the surface of dry homogeneous GM. The desert dwelling snake *Chionactis occipitalis* travels quickly (30-80 cm/s N=10 individuals, 32 trials) using a stereotyped shape. Surface drag measurements revealed that the ratio of thrust to drag forces, a critical component in undulatory motion, did not depend on speed or depth; like *C. elegans* the snake motion was non-inertial. We developed a surface resistive force theory (RFT) which revealed the snakes' waveform maximized center-of-mass speed given a constraint on peak muscle power. We explored the real-world impact of changing waveform using a robophysical model, a 10-link robot snake. When the robot re-encountered previously disturbed material the effectiveness of the motion was reduced-often the robot completely failed to make forward progress-and RFT over-predicted performance. The snakes' waveform is in the regime where motion is like that in a frictional fluid; by limiting material yield the animal avoids contending with the memory-dependent effects that led to robot failure.

P3-1 SCHLEIFER, HJ*; ELLERS, O; JOHNSON, AS; Bowdoin College; *hjschlei@bowdoin.edu*

Using circuit theory to model flow and pressure outputs of the circulatory system of the American lobster, Homarus americanus

Interest in modeling the human circulatory system has driven a significant amount of research on the topic, resulting in well-developed models based in electric circuit theory. This raises the question, however, of whether this model can be applied to morphologically different organisms with pulsatile hearts. Additionally, the circuitry-based model of the human circulatory system has been used extensively in modeling the behavior of isolated parts of the human circulatory system, where very few have tried building a comprehensive model of the entire circulatory system. This project, therefore, has two major objectives: applying the electrical circuitry analogy to the circulatory system of the lobster, and stringing together a model of the entire system, instead of multiple models of isolated parts of the system. Similar to mammalian circulatory systems, lobsters have a circulatory system made up of compliant vessels, suggesting that the Windkessel pump circuitry theory can apply to lobster as well as human vessels. These systems differ, however, in a few fundamental ways: the lobster heart only has one chamber, there are seven vessels leaving the lobster heart instead of the one leaving the human heart, and the lobster has an open circulatory system instead of the closed mammalian circulatory system. These differences suggest that models built around the human circulatory system would need to be modified to model the lobster circulatory system. From initial analysis, in a system of compliant vessels (treated as individual Windkessel units), increasing compliance with distance from the heart produces a pulse-smoothing effect. Pulse smoothing reduces fluctuation in power in the outer vessels. Compliance also appears to affect the filling and emptying of vessels, causing vessels to fill in a staggered fashion.

77-5 SCHNITZLER, CE*; NGUYEN, A-D; KOREN, S; GAHAN, JM; BARREIRA, S; SANDERS, SM; PHILLIPPY, A; MULLIKIN, J; CARTWRIGHT, P; NICOTRA, M; FRANK, U; BAXEVANIS, AD; Whitney Lab, University of Florida , NHGRI, NIH, SARS, University of Pittsburgh , University of Kansas, NUI-Galway; *christine.schnitzler@whitney.ufl.edu*

New Kid on the Block: Placing the Hydractinia Genome within the Context of Established Cnidarian Genomes

Cnidarian genomes provide a framework for exploring fundamental biological processes such as embryonic development, regeneration, self-recognition, and aging. We are focusing on the colonial cnidarian *Hydractinia*, a hydrozoan representative that has incredible regenerative ability largely due to a lineage of migratory stem cells known as ‘i-cells'. In this system, one can study gene function using several established functional genomics tools, including CRISPR/Cas9 genome editing. We have generated high-quality, high-coverage genome and transcriptome assemblies for *H. echinata* and its sister species, *H. symbiolongicarpus*, using PacBio long-read and Dovetail-based strategies for the genome and Illumina data for the transcriptome. The length of the genome assemblies are 419 Mb for *H. echinata* (84x coverage, 1,582 scaffolds, N50 of 1.51 Mb) and 308 Mb for *H. symbiolongicarpus* (94x coverage, 392 scaffolds, N50 of 3.31 Mb), placing them among the most contiguous invertebrate genomes. Similar to *Hydra*, both genomes are AT-rich (65%) and highly repetitive (>50%). We are using a comparative genomics approach that includes ortholog clustering to determine how closely these genomes resemble other established cnidarian model genomes. Our results reveal both the conserved features and extensive evolutionary novelties contained within these *Hydractinia* genomes.

132-6 SCHRAFT, H*; BAKKEN, G; CLARK, R; San Diego State University, University of California Davis; *haschraft@ucdavis.edu*

Infrared-sensing snakes select ambush orientation based on thermal backgrounds

Sensory information drives the ecology and behaviour of animals and some animals are able to detect environmental cues unavailable to us. For example, rattlesnakes use infrared (IR) radiation to detect prey. The IR sensory system should best detect warm prey animals against cool and thermally uniform backgrounds. In addition, prey may be more easily detected at thermal transitions, i.e. areas where contrast between a moving target and background changes rapidly. We tested whether rattlesnakes select ambush positions with backgrounds that offer strong thermal contrast with endothermic prey and/or backgrounds with thermal transitions. We tracked free-ranging sidewinder rattlesnakes *Crotalus cerastes* to their selected ambush sites and recorded 360° near-ground thermographic panoramas from the center of the ambush site. A computer simulation then moved a simulated prey item across the panorama and computed contrasts at each azimuth. Rattlesnakes did not choose ambush directions that offered stronger contrast than average, but they did choose directions with stronger thermal transitions. Selecting such ambush directions presumably facilitates prey capture at night when visual cues are reduced. Future laboratory and field work will determine whether strike probability and success are indeed higher when facing thermal backgrounds with strong thermal transitions.

P3-139 SCHREY, A*; RUSSELL , A; LIEBL, A; Georgia Southern University, University of Exeter, University of South Dakota; *aschrey@georgiasouthern.edu*

Temporal Variation in DNA Methylation Among Chestnut Crowned Babbler from Three Developmental Periods

Ecologically important variation in DNA methylation can be induced by changes in local environment, allowing DNA methylation to vary over an individual's development. We compared DNA methylation among three developmental periods (i.e. at hatching, just before fledging, and as an adult) in multiple chestnut crowned babblers (*Pomatostomus ruficeps*); this allowed us to track changes in DNA methylation over time within a single individual. Our objective was to determine how liable DNA methylation is among developmental periods, and to determine the amount of induced change within individuals. Using the epiRADseq protocol we were able to generate 148,881 unique fragments indicating considerable variation in DNA methylation among individuals as well as within individuals through time. Equally, although differences existed through time at some sites, other sites remained relatively stable through time. Broadly, we show here that differences among individuals exist in methylation profile but that portions of these profiles are not stable over time, suggesting the environment is also an important player in the induction of different epigenetic states at multiple points in life.

P3-172 SCHULTZ, EM*; ANGELO, CM; BRUSH, JJ; REICHARD, DG; Kenyon College, Ohio Wesleyan University; *schultz1@kenyon.edu*

The Effect of a Short-term Stressor on Immune Investment in Female House Wrens Using a Simulated Predation Attempt

Because energy is finite, organisms must be strategic about how and when energy is allocated to competing physiological processes. Corticosterone, an immunomodulatory hormone, has been hypothesized to enhance immune function in response to stressors of short duration and to suppress immune function in response to long-term stressors. In this study, we examined the effect of a short-term stressor on allocation to immune function in female House Wrens *Troglodytes aedon* . Specifically, we exposed experimental females (n=13) with 2-6 day old nestlings to a five-minute simulated predation event using a model snake, a common nest predator. During this time, we recorded anti-predator behaviors such as flyovers, attacks, alarm calls, and the amount of time spent within 1 m and 5 m of the nest. At the end of the trial, the snake was removed and the female was captured within 0-13 min post-trial (mean=7.5 min). A blood sample was collected within three minutes following the female's capture and used to measure bacterial killing ability (*E. coli*), leukocyte counts, and plasma corticosterone levels. Control females (n=14) with 2-6 day old nestlings were not exposed to the simulated predator presentation but were caught and sampled identically to experimental females. Experimental females had significantly higher bacterial killing ability than control females (t=-2.87, df=25, p=0.008). Differences in leukocyte differentials and anti-predator behaviors between experimental and control females will be presented. Results suggest that failed predation events may enhance immunity over a short time scale, which is consistent with a complex relationship between stress and immune function in a free-living system.

68-8 SCHULZ, AK*; WU, JN; HU, DL; Georgia Institute of Technology ; *akschulz@gatech.edu*

Elephants wrap their trunks around objects to better distribute forces

Elephants are the construction cranes of the animal kingdom with the ability to move and lift unwieldy objects with their trunks. In this experimental study, we examine the kinematics of an elephant lifting a barbell. We show that the elephant trunk has several constraints to lift an object in this fashion. The trunk forms a J shaped structure with two sections of the trunk forming arch-like shapes to resist deformation. To resist the bar sliding from the elephant's grip, the elephant must also wrap the tip of its trunk around the bar, in wrapping angles that increase with the amount of weight. We rationalize both the shape of the trunk and wrapping angle using mathematical models involving the trunk's elastic modulus. While wrapping the trunk increases both its angle and area of contact to lift the barbell. These findings may inspire work in elephant-inspired soft robotics.

81-5 SCHWANER, MJ*; FREYMILLER, GA; WHITFORD, MD; HIGHAM, TE; CLARK, RW; MCGOWAN, CP; University of Idaho, Moscow, San Diego State University, San Diego, University of California, Riverside; *janneke.schwaner@gmail.com*

Tail Rotation Facilitates Active Body Reorientation during Escape Responses in Kangaroo Rats (D. deserti)

Desert kangaroo rats (*D. deserti*) use erratic leaps to evade predation by snakes. During these vertical jumps, these animals rotate their relatively long tail, as well as their body, through the air. Previous behavioral research on tail use in these rodents suggested that the tail is mainly used for balance. Video recordings show large tail swings in combination with a change in body orientation. Given these observations, we hypothesized that these kangaroo rats use their tail to change body orientation in the aerial phase of the escape response in addition to use it for balance. To test this hypothesis, we collected video data from kangaroo rats in the field, while they performed the leaps as a response to a self-built, artificial predator attack simulator. For analysis we quantified rotation in the yaw plane for both the body and the tail from take-off to landing. In the yaw plane, the tail performs one full rotation in approximately 0.14 - 0.2 seconds while the body turns 35 - 55 degrees during the aerial phase (when legs are retracted). This suggests that kangaroo rats use their tail actively to change orientation while airborne and that they likely need to reach certain jump height to have sufficient time to perform enough tail rotations to actively change orientation before touching the ground. Future analysis will include body and tail angle change in the roll and pitch plane, as well as analysis of the head rotation with respect to the body.

P2-29 SCHWARTZ, TS; KLABACKA, RL*; GANGLOFF, EJ; BRONIKOWSKI, AM; Auburn University, Station d'Ecologie Théorique et Expérimentale du CNRS, Iowa State University; *klabacka.randy@gmail.com*

Population genetics of the electron transport chain in snake populations exhibiting divergent resting metabolic rates.

Although evidence for the importance of mitochondria in the evolution of natural populations continues to accumulate, studies attempting to link natural variation in mitochondrial function to mitochondrial DNA (mtDNA) variation and/or environmental variation have had mixed reports. Variation in mtDNA contributing to variation in metabolic rates can, in turn, be expected to drive differences in how organisms process energy from their environment. Previously we documented two distinct ecotypes of western terrestrial garter snakes (Thamnophis elegans) with differences in mitochondrial function, reaction norms of metabolic rate to temperature, and mtDNA sequence data. While mtDNA contributes significantly to processes within mitochondria, most gene products involved in mitochondrial function originate within nuclear DNA (nDNA). The electron transport chain (ETC), the centre for ATP production, is composed of 13 mtDNA-coded proteins and 73 nDNA-coded proteins. Here we use an expanded sequence-capture genomic sequence dataset from 96 individuals of the same and additional populations to validate previous findings that the ecotypes have unique mtDNA haplotypes with two amino acid changes in ND5 and CYTB that are highly segregated between ecotypes. This striking population structure at the mtDNA is in contrast to the low genetic structure seen in the background nDNA. We now incorporate analyses from the nDNA-coded ETC genes, comparing several bioinformatics approaches for sequence assembly and extraction of SNP data. Contrasts between the variation in mtDNA-coded and nDNA-coded ETC genes are made at the level of the gene, protein, and ETC complex and interpreted in the context of mitochondrial physiology and function.

90-3 SCHWARTZ, LC*; TRUEBANO, M; HILBISH, TJ; University of South Carolina, Plymouth University; *schwarl@email.sc.edu*

The Physiology and Transcriptomics of Thermal Tolerance in Mytilus Mussels

Climate change has already resulted in range shifts of a variety of species, as well as changes in the timing of various phenological events. As climate change continues these biological effects will become more pronounced. This work concerns the effects of warming waters on the physiology and gene expression of blue mussels. The blue mussel species complex is comprised of the congeners *Mytilus trossulus*, *M. edulis*, and *M. galloprovincialis*, which form a biogeographic replacement series with respect to temperature. We focus on the cold-temperate *M. edulis* and the warm-temperate *M. galloprovincialis*, which are physiologically and genetically distinct, yet hybridize readily, forming extensive hybrid zones. Closely related, but physiologically distinct species make ideal systems for studying the impacts of climate change, and this system is especially valuable due to the presence of natural hybrids. In this study we sampled individuals from putatively pure populations on either side of a hybrid zone and acclimated them to either 15°C or 23°C for 14 days in order to evaluate the animals' response to persistent, lower level warming. Feeding rate and respiration rate were recorded at the end of 14 days, and RNA was extracted from the gills for RNA-seq. We showed that, despite being in close geographic proximity these populations differentially respond to sub-lethal temperature challenges. We then conducted an exploratory analysis of the transcriptional responses of these populations to identify putative regulatory differences that may provide the basis of species-specific differences in physiological responses to chronic sublethal temperature challenges. Future studies will utilize hybrid individuals to assess the co-segregation of physiological and transcriptomic adaptations of these two species in relation to changing climate.

S5-10 SCHWARTZ, Tonia/S; SCHWARTZ, Tonia; Auburn University; *tss0019@auburn.edu*

Using Transcriptomics to Further our Understanding of the Divergent Effects of Stressors on Physiology, Life History and Fitness

Not all environmental stressors are equivalent in terms of how they shape the life history and fitness of an organism. Yet, we have limited understanding of where in the processing of different environmental stressors divergence occurs and how this translates to the organismal level. Additionally, the response to a stressor maybe be dependent upon the context in which it is received — i.e., the other stressors the animal may experience in their environment or their genetic background. Transcriptomics can be used to characterize the genomic responses in a context specific manner and translate these responses to how they effect the cellular, physiological and organismal levels. Here I discuss what we have learned from multiple "molecular stress response" studies that include analyses at the transcriptomic level. I specifically focus on how transcriptomic responses to different stressors can diverge (despite having a similar corticosterone responses), how genetic background can alter the response to a stressor, and how a primary stressor can alter the response to a secondary stressor. These studies use ecologically relevant environmental stressors with either Daphnia where we can directly measure fitness (i.e. lifetime reproductive output), or in reptiles where we can link tissue-specific transcriptomic responses to physiology and life history.

117-2 SCHWARZ, D*; HEISS, E; KONOW, N; Friedrich-Schiller-University Jena, University of Massachusetts Lowell; *daniel.schwarz@uni-jena.de*

Three-dimensional mandibular movements during chewing in a salamander

Food processing describes any kind of mechanical reduction or preparation of food items prior to deglutition. The most commonly used processing mechanism in gnathostomes is ‘chewing'. Chewing is defined as any form of intraoral processing by rhythmic jaw movements and represents the most common processing mechanism in tetrapods. Non-mammalian tetrapods typically have a hinge-like jaw joint that only permits simple arcuate (open/close) movements of the mandible during chewing. By contrast, the specialized jaw systems in most mammals permit complex 3-D movements of the mandible involving propalineal (longitudinal) as well as transverse (lateral) movements. However, only limited information is available on intraoral processing mechanisms in reptiles and lissamphibians. In fact, it was generally accepted that many reptiles and most lissamphibians do not process food intraorally but rather swallow it whole and unreduced. Here, we use biplane high-speed fluoroscopy and 3D kinematics analyses to show that the neotenic salamander *Siren intermedia* not only uses intraoral food processing but also relies on a mandibular motion pattern involving propalineal (11.72 ± 3.49 % of cranial length) as well as transverse (4.95 ± 2.05 ° angular displacement at the mandibular symphysis) movements. The mandibular motion pattern seen in *Siren* involves a complexity not previously documented for non-mammal tetrapods. Our data on intraoral food processing in lissamphibians also challenge the commonly held view that complex chewing movements are restricted to mammals.

58-2 SCHWEIKERT, LE*; CAVES, EM; FITAK, RR; SOLIE, SE; SUTTON, TT; JOHNSEN, S; Duke University, Nova Southeastern University; *lorian.schweikert@gmail.com*

Patterns and Predictors of Spectral Sensitivity Variation in Fishes

Of all vertebrates, why fishes show the greatest diversity in spectral sensitivity remains an open question in the field of sensory ecology. Over the past several decades, rod and cone spectral sensitivity data have been amassed for hundreds of fish species, yet varying trends across clades make it difficult to identify the major factors influencing variation in this trait. Here, rod and cone λmax (photoreceptor class peak sensitivity) and chromacy (photoreceptor class number) values were compiled for a meta-analysis examining the ecological basis and functional significance of spectral sensitivity diversity in fishes. Examining rod sensitivity, linear models that correct for phylogenetic relatedness showed that rod λmax values, varying over just 64 nm, are best predicted by habitat and depth. A potential influence of environmental temperature was also identified, as fishes in temperate latitudes had longer wavelength rod λmax than those in the tropics. Examining patterns of cone spectral sensitivity showed that trichromacy was most common, ultraviolet λmax values were found exclusively in trichromacy and higher chromacy levels, and increasing chromacy, including from tetra- to pentachromacy, significantly increases sensitivity range. Using a recently developed method of multivariate phylogenetic latent liability modeling, depth, diet, body coloration, and body size of fishes were found correlate to chromacy level; however, after applying phylogenetic correction, the only remaining correlated predictor was depth. Together, this work shows ecological patterns of spectral sensitivity across ray-finned fishes, stressing the importance of considering phyletic heritage in studies of spectral sensitivity and suggesting that selection can act on even the smallest differences in sensory ability.

P2-182 SCHWIETERMAN, GD; WINCHESTER, MM*; SHIELS, HA; MARSHALL, HM; BUSHNELL, PG; BRILL, RW; BERNAL, D; Virginia Institute of Marine Science, Univ. of Massachusetts, Dartmouth , Univ. of Manchester, Atlantic White Shark Conservancy, Indiana University, South Bend; *maggiewinchester4@gmail.com*

The Impact of Simulated Capture Stress on Elasmobranch Cardiac Function using Isolated Myocardial Strips

Recent work on capture stress in sharks suggests that elevated levels of potassium in the blood (i.e., hyperkalemia) may be correlated with higher rates of post-release mortality. In teleosts, the negative effects of hyperkalemia appear to be exacerbated when combined with other common by-products of the stress response (i.e., hypoxia, acidosis) or with unfavorable environmental conditions (i.e., elevated temperature). This study investigates how hyperkalemia (7.4mM K^+), hypoxia, acidosis (0.26 pH decline) and changes in temperature may affect myocardial function in three phylogenetically disparate (but sympatric) species of elasmobranchs (sandbar shark, smooth dogfish, and clearnose skate). We measured myocardial strip contractility and force production *in vitro* and evaluated the ability of a β-adrenergic agonist to ameliorate negative effects of simulated capture stress. All species demonstrated declines in the net force of contraction in response to hyperkalemia but only sandbar sharks showed a significant decline in force when compared to baseline levels of potassium (5 mM K^+, $p = 0.001$). Clearnose skates were the only species to show a decrease in net force in response to hypoxia and acidosis ($p=0.026$) as well as in response to high temperature ($p=0.0002$). This study provides the first indication that hyperkalemia may negatively affect heart function in some elasmobranchs, however, there are likely important interspecific differences that allow varying tolerances to hyperkalemia resulting from capture-related stress.

P3-52 SCIBELLI, A E*; AONUMA, H; TRIMMER, B A; Tufts University, Medford, MA, USA, Hokkaido University, Hokkaido, Japan; *anthony.scibelli@tufts.edu*

Proleg muscles in Manduca sexta: Segmental differences suggest anteroposterior specialization.

Larval *Manduca sexta* have become an important model system for understanding the neuromechanics of soft body locomotion. In addition to *Manduca*'s readily accessible nervous system, its tissues and body structures have been described in increasing detail throughout the 20th century. While dissection techniques and talent have captured most of the musculature and body wall, they all rely on flattening the three-dimensional structure which causes considerable distortion and tissue damage. To gain better insights into the control and mechanical properties of the abdominal prolegs we have used X-ray microtomography of intact animals to capture structures at tens of micron of resolution. Here we describe intact proleg muscle morphology, highlighting previously undiscovered fiber bundles and attachments, as well as differences in fiber quantity and attachment area between anterior and posterior segments. Larvae were fixed, stained and scanned to distinguish the primary tissues types with minimal distortion. Structures were labelled and morphological statistics were calculated from these three-dimensional models. In addition to muscles described in the literature attached to the proleg planta (PPRM), we found three previously undescribed groups of fibers that attach to the body wall in a highly stereotyped manner. Data from several animals revealed an increased number of fibers in specific muscle groups in posterior segments. Additionally, there is a reduction in the cross-sectional area of individual fibers and a greater total muscle volume. Total fiber volume for all muscles inserting in the planta show an approximately two-fold increase from segments A3 to A6.

3-3 SCKRABULIS, JP*; MESSNER, ML; MCWHINNIE, RB; ANSARI, HD; RAFFEL, TR; Oakland University; *jason.sckrabulis@gmail.com*

Environmental Predictors of Avian Schistosome (Swimmer's Itch) Abundance Among Michigan Inland Lakes

Avian schistosomes are snail-borne trematode parasites (*Trichobilharzia* spp.) that can cause a nasty skin rash in humans when their cercariae mistake us for their normal bird hosts. The aim of this study was to investigate the spatial drivers of *Trichobilharzia* spp. cercaria abundance throughout Northern Michigan inland lakes. For 38 sites on 16 lakes, we measured and assessed several dozen potential environmental predictors that we hypothesized might drive overall cercaria abundance, including local densities of intermediate and definitive hosts, temperature, water chemistry parameters, water clarity and growth rates of algal periphyton (snail food), physical characteristics of each lake and local site, zebra mussel (*Dreissena* spp.) abundance, and local abundance of predatory crayfish. We also measured daily abundance of schistosome cercariae in the water over a 5-week period, with support from local citizen scientists who collected and preserved filtered water samples for later qPCR analysis. The best and highly significant predictor of cercaria abundance was host *Stagnicola* spp. snail density, suggesting that intermediate host abundance is the primary driver of avian schistosome abundance in these lakes. We also found a significant negative relationship between cercaria abundance and submerged aquatic vegetation, possibly due to direct negative effects of vegetation on cercaria survival or movement (i.e., influx from deep-water offshore snail beds). If these effects are found to be causal, then managing the abundance or types of vegetation in the riparian zone could provide new tools for reducing swimmer's itch risk in northern MI lakes.

S4-7 SEAGO, AS; NSW Department of Primary Industries; *ainsley.seago@dpi.nsw.gov.au*

The Evolution of Photonic Crystals in Beetles

Insect structural colors span an astonishing range of optical effects and photonic mechanisms, from simple thin-film reflectors and diffraction gratings to three-dimensional photonic crystals. This talk explores the evolutionary origins of that structural diversity and its growing potential for biomimetic engineering.

S10-5 SEARS, MW*; RIDDELL, EA; ANGILLETTA, MJ; Clemson University; *Thermalecology@gmail.com*

Shifting environmental stressors across ontology in vertebrate ectotherms

Many organisms experience distinctly different abiotic environments across their lifetimes. For instance, in terrestrial oviparous species, developing embryos experience microclimates selected by their mothers without the opportunity for behavior to alleviate any stresses of that environment; whereas, adults are mobile and can use behavioral strategies to offset thermal and hydric stress. Further, as a consequence of body size, juveniles become more independent from environmental stresses as they grow to adulthood. With larger body size, physiological trade-offs can become more important in mediating stress. Here, we review data to explore how the relationships between the abiotic environment and trade offs between behavior and physiology shift across life stages in salamanders and lizards.

88-1 SEBENS, KP; University of Washington; *sebens@uw.edu*

Evaluating Trait-Environment Interactions Using Measures of Performance Linked to Fitness and Population Response Models

As environmental conditions change in space and time, they alter fitness through effects on processes including energy acquisition, mechanical performance, metabolic cost, growth rate, survivorship and reproductive output. Organisms can respond by altering their morphology, material composition, physiology and life histories via phenotypic plasticity or by genetic change in populations. Researchers considering the interaction of environmental variables and traits typically concentrate on particular components of fitness, although methods exist to calculate a population level estimate of average fitness, for a set of identical individuals with a designated set of traits. Such models can also estimate future population responses in the field, based on predicted environmental change (e.g. climate change). Components of fitness (performance measures) are not always good predictors of fitness or population response; they can differ in both direction and magnitude. As an example, one set of environmental conditions could maximize growth and lifetime reproduction, but could also result in higher mortality (e.g. wave-induced dislodgment), and thus lower fitness, compared to an energetically less optimal environment. Here, energetics models formulated for growth and allocation are combined with models that calculate population growth rate. Both intertidal and subtidal invertebrates are used as examples, where there is a hypothesized energetic trade-off between shell and attachment production (affecting survivorship), and how energy is allocated toward growth, final size and reproduction. Here, one such model is used to examine effects of environmental variability on fitness, fitness components, and phenotypic variability in critical traits (including body size) and to determine an optimal set of conditions where fitness is maximized.

P1-42 SEBER, E.K.*; KARAKAS, F.; MURPHY, D.W.; BYRON, M.L.; Penn State University, University of South Florida; *elizabeth.k.seber@gmail.com*

Fluid dynamics of ciliary propulsion at intermediate Reynolds number: locomotion across ontogeny in the Atlantic ctenophore Mnemiopsis leidyi

Ctenophores, at 1 - 15cm in length, are the largest organisms which rely exclusively on cilia for locomotion. In contrast to "typical" cilia, which are a few microns long and operate at Reynolds numbers (Re) much less than one, ctenophore cilia are around a millimeter long and arranged into platelike structures called ctenes, which have $10 < Re < 300$. We investigated the scaling of cilia morphology and beat kinematics within a single ctenophore species, the lobate comb jelly *Mnemiopsis leidyi*. Using specimens in various stages of development, ranging from 0.6 to 4.5cm in length, we measured body size, ctene length, and ctene spacing. We found that while ctene length increases linearly with body size, ctene spacing increased nonlinearly. We used several synchronized high-speed video streams of actively swimming animals to measure kinematic variables such as ctene beat frequency, which were then correlated with 3D-reconstructed bulk variables such as overall body velocity. During passive drifting, we found that animals maintained a relatively constant beat frequency across a large range of body sizes and developmental stages. To further elucidate these differences and similarities, we performed Particle Shadow Velocimetry (PSV) on the actively-beating ctene rows of several size classes, allowing us to calculate the velocity and vorticity fields around the ctenes. These results yield valuable insight into changes in locomotor strategy across ontogeny in ctenophores, and more generally into the operation of flexible propulsors at the milliscale.

113-4 SECOR, S.M.*; KAY, J.C.; PERRY, B.W.; CASTOE, T.A.; SECOR, Stephe; University of Alabama, University of Texas, Arlington, University of Texas, Arlington; *ssecor@ua.edu*

The Underlying Mechanisms that Drive Divergent Intestinal Phenotypic Responses to Feeding in Snakes

Snakes exhibit a clear dichotomy in the capacity to regulate intestinal performance with each meal. Frequently-feeding species narrowly regulate intestinal function with feeding, whereas infrequently feeding species up and down regulate intestinal form and function with the start and finish of each meal. Driving this divergence in postprandial response is the lack of any change in microvillus length and absorptive surface for frequently-feeding snakes compared to the 3- to 5-fold lengthening of the microvilli and matched increases in intestinal function with feeding characteristic of infrequently-feeding species, a response that is reversed after digestion has completed. We are taking advantage of this distinct dichotomy in intestinal response and the link between form and function, to explore the signaling, cellular, and molecular mechanisms that underlie these divergent responses. Our comparative approach is allowing us to identify specific gene expression programs and regulatory pathways responsible for the synthesis, mobilization and insertion of microvillus and membrane proteins involved in the postprandial remodeling of the brushborder membrane for infrequently feeding snakes. Our results indicate that feeding activates pathways related to the nucleation and elongation of actin filaments for infrequently-feeding species. Centered in such pathways are the regulatory activities of Rho-family GTPases, known regulators of cytoskeleton dynamics and proposed regulators of microvillus formation. Although the phenotypic responses of the intestine are convergent among infrequently-feeding snake lineages, explored is whether the underlying molecular programs have evolved independently. Support provided by NSF IOS (SMS) 0466139 and IOS 1656138 (SMS & TAC).

P1-193 SEGUEL, Mauricio*; MONTALVA, Felipe; DIEGO, Perez-Venegas; JOSEFINA, Gutierrez; NICOLE, Gottdenker; University of Georgia, Pontificia Universidad Catolixa de Chile, Universidad Andres bello, Universidad Austral de Chile; *mseguel@uga.edu*

Immune mediated hookworm clearance and survival of a marine mammal decreases with warmer ocean temperatures

Increases in ocean temperature are associated with changes in the distribution of fish stocks, and the foraging regimes and maternal attendance patterns of marine mammals. However, it is not well understood how these changes affect offspring health and survival. The maternal attendance patterns and immunity of South American fur seals were assessed in a rookery where hookworm disease is the main cause of pup mortality. Pups receiving higher levels of maternal attendance had a positive energy balance and a more reactive immune system. These pups were able to expel hookworms and survive the infection through a specific immune mediated mechanism that involved production of parasite specific IgG and prolioferation of Th2 leukocytes. Maternal attendance was higher in years with low sea surface temperature, therefore, the mean hookworm burden and mortality increased with sea surface temperature over a 10-year period. We provide a mechanistic explanation regarding how changes in ocean temperature and maternal care affect immunity and infectious diseases dynamics in a marine mammal.

P1-179 SEHRSWEENEY, M*; WILSON, D; BAIN, M; BOUTIN, S; HUMPHRIES, MM; LANE, JE; MCADAM, AG; DANTZER, B; University of Michigan, Memorial University, University of Guelph, University of Alberta, McGill University, University of Saskatchewan, University of Guelph; *dantzer@umich.edu*

Effects of acute stress and glucocorticoids on acoustic structure of territorial vocalizations of North American red squirrels

Acoustic signals are an important way in which animals communicate with another and vocalizations may convey much information about the state of the signaler to receivers such as their sex, age, or individual identity. Less is known about the ability of acoustic signals to communicate labile information to receivers, such as short-term changes in hormone levels. We examined the influence of changes in physiological stress state on the acoustic structure of the territorial vocalizations of wild North American red squirrels (*Tamiasciurus hudsonicus*) known as rattles. We assessed the effects of physiological stress state on the acoustic structure of rattles by applying an acute stressor (trapping and handling the squirrels) and by treating squirrels with exogenous glucocorticoids (GCs). We characterized the acoustic structure of rattles emitted by these squirrels by measuring rattle duration, mean frequency, and entropy. Our results provide mixed evidence that rattles show a "stress signature". Squirrels experiencing an acute stressor produced rattles that were dramatically different from those recorded from squirrels at baseline conditions. However, the same shifts in rattle acoustic structure were not observed when squirrels were treated with GCs compared to those fed supplemental food or those that were unmanipulated. Our results indicate that acute stress impacts the acoustic structure of vocalizations but changes in circulating GC levels are not solely responsible for such changes.

P2-214 SEIDEL, R; CHAUMEL, J; HERBERT, A; MORENO-JIMENEZ, I; SUMMERS, A; DEBIAIS-THIBAUD, M; DEAN, MN*; MPIKG, U Alaska, U Washington, U Montpellier; *mason.dean@mpikg.mpg.de*

Mineralization in Chimaera Cartilage: Tessellated but not Tesserae?

An accepted uniting character of cartilaginous fishes (sharks, rays, chimaera) is the presence of mineralized tiles (tesserae) on the outside of the cartilage skeleton. Tesserae have, however, never been demonstrated in modern chimaera and it is debated whether the skeleton mineralizes at all. We use materials and biological tissue characterization techniques to show, for the first time, the presence of a tessellated mineralized layer in chimaeroid fish, in several skeletal elements (jaws, cranium, vertebral column) and three genera. The mineralized "tiles" are irregular and not uniformly distributed, unlike most shark and ray tesserae, yet share several features with tesserae. The mineralized layer is peripheral in the unmineralized cartilage and seems to grow by periodic accretion of mineral at edges, forming laminated patterns of mineral density variation similar to those in shark and ray tesserae (e.g. in Liesegang lines, hypermineralized "spokes"). Chimaeroid mineralized cartilage, however, appears to lack the network of cell spaces that characterize tesserae, although we observe poorly mineralized regions suggesting infilled cell spaces. Significant is the apparent absence of the cell- and fiber-rich joints that link shark and ray tesserae, suggesting that cells and true intertesseral joints may be vital to the development of more geometric tessellations. Our data indicate that skeletal mineralization is more widespread and diverse in extant cartilaginous fishes than previously thought; developmental studies of chimaeroid mineralization are necessary to determine the mechanisms underlying skeletal patterning and their conservation across cartilaginous fishes.

60-1 SENDALL, KM*; MONTGOMERY, RA; STEFANSKI, A; REICH, PB; Georgia Southern Univeristy, University of Minnesota; *ksendall@georgiasouthern.edu*

Effects of experimental warming on invasive Rhamnus cathartica as compared to native temperate and boreal tree species

Boreal Forest Warming at an Ecotone in Danger (B4WarmED) is a manipulative open-air experiment in northern Minnesota, addressing the potential for climate warming to alter tree function and species composition at the boreal-temperate forest ecotone. The goal of this study was to compare plant traits of tree species from three groups (invasive temperate, native temperate, and native boreal) grown under two temperature regimes (ambient and warmed 3.4 °C) to determine whether an aggressive invasive species is differentially sensitive to climate warming than common native species. We present data collected over four years on tree seedling growth, leaf emergence and senescence, leaf gas exchange rates, and leaf nutrients of 11 species. Native boreal species showed a decline in growth under the warming treatment, while native temperate and the invasive temperate (*Rhamnus cathartica*) species generally responded positively to warming. However, the invasive *R. cathartica* showed the largest increase in growth. This growth response to warming by the invasive species does not appear to be driven by differences in growing season length, as all species extended their growing season in the warmed plots. Specific leaf area (SLA) of both native groups did not vary among treatments, but SLA of *R. cathartica* declined significantly in the warming treatment, causing increased area-based leaf nitrogen concentrations. Area-based photosynthetic rates followed a similar pattern, increasing in the warming treatment for *R. cathartica*, but remaining stable or declining in the two native groups. Our growth and leaf trait results suggest that invasive *R. cathartica* may outgrow and outcompete the native species in northern Minnesota under climate change.

29-7 SENNER, N.R.*; SASSER, K.T.; WOLF, C.J.; VELOTTA, J.P.; SCHWEIZER, R.M.; STAGER, M; CHEVIRON, Z.A.; University of South Carolina, University of Montana; *nathan.senner@gmail.com*

The Effect of Aerobic Performance on High-Elevation Deer Mouse Survival

Physiological traits are often hypothesized to directly influence fitness. Relatively few studies, however, have actually been able to quantify this link, nor investigate how the relationship may vary across environmental gradients. One such physiological trait frequently thought to be correlated with fitness is aerobic performance: numerous studies have found evidence that enhanced aerobic performance has evolved at high elevations where the partial pressure of oxygen is significantly reduced. What remains unclear, though, is how strongly and regularly selection is acting on populations and whether the strength of that selection varies with elevation or levels of connectivity among populations. To explore the link between physiology, gene flow, fitness, and elevation, we quantified how an individual's aerobic performance affected the survival of deer mice, Peromyscus maniculatus, along two transects spanning an elevational gradient in the Colorado Rockies from 2200 - 4300 m. We found that the strength of selection on aerobic traits was strong at mid-elevations — from 2200 - 3000 m — but weak at higher elevations. Furthermore, higher elevation populations exhibit reduced phenotypic variation, as well as reduced genetic variation for genes under selection. This suggests a history of strong selection at high elevations, but also that high-elevation populations may now be locally adapted. Thus, although extreme environments are thought to regularly push extremophiles close to the edge of their physiological capabilities, consistent directional selection may enable populations to become locally adapted to even the harshest conditions.

137-6 SERB, JM*; SMEDLEY, GD; AUDINO, JA; Iowa State Univ., Univ. São Paulo; *serb@iastate.edu*

Evolution of morphologically complex eyes in the Pectinoidea (Mollusca: Bivalvia)

Eyes have evolved numerous times during the evolution and diversification of molluscs. One of the most diverse families of bivalves, the scallops (Pectinidae), have a complex sensory system that includes several hundreds of eyes on a single animal. These single chambered eyes include a mirror-like reflector lining the back of the eye which focuses light onto a double-retina system in the middle of the eye. Other lineages in the superfamily Pectinoidea less morphologically complex eyes. To understand phenotypic evolution, the Pectinidae needs to be placed in a deeper phylogenetic framework within the Pectinoidea. We reconstructed a molecular phylogeny for 60 species from four of the five extant families within the Pectinoidea using a five gene dataset (12S, 16S, 18S, 28S rRNAs and histone H3). Our analyses give consistent support for the non-monophyly of the Propeamussiidae, with a subset of species as the sister group to the Pectinidae, the Propeamussidae type species as sister to the Spondylidae, and the majority of propeamussiid taxa sister to the Spondylidae + Pr. dalli. This topology represents a previously undescribed relationship of pectinoidean families. Our results suggest a single origin for eyes within the superfamily and likely multiple instances of loss associated with habitat shifts.

20-4 SETH, D*; KACZMARCZIK, M; Villanova University, Academy of Natural Sciences of Drexel University; *deeksha.seth@villanova.edu*

Integration of Biology and Engineering for K-12 Students

Integration in science, technology, engineering and mathematics (STEM) education is becoming increasingly important to enhance students' creative thinking and problem-solving skills and to teach students how different disciplines work in harmony, especially biology and engineering. While integration between biology and engineering is found in higher education and graduate research, we have yet to successfully transfer such ideas to formal or informal K-12 programs. The most common form of integration seen involves the use of technology while teaching traditional science topics; for example, using a tablet to learn about anatomy. The goal of our project is to develop, implement and assess a new five-step framework that can allow K-12 biology, applied science, and engineering educators to present material to students in an integrated manner. The framework enables the educator to explore biological principles related to a physiological system, such as an animal, that can be quantified or explained using common engineering principles such as conservation of energy, buoyancy etc. Initial studies, including online interviews and surveys, show great interest from educators but also significant skepticism because of lack of preparation and knowledge in both fields simultaneously. Therefore, in addition to providing the framework, our long-term goal is to develop a repository of integration ideas, tools and activities that teachers with all educational backgrounds can adopt without it demanding extensive time, cost or preparation. This framework also serves as a guiding model for the development of bio-inspired educational tools for museums and K-12 classrooms. We believe the integration of STEM disciplines in K-12 programs can expose future scientists and engineers to the collaborative and innovative nature of STEM fields, and therefore increase their interest and engagement in the respective fields.

P1-175 SEWALL, KB*; BECK, ML; Virginia Tech, Rivier University; *ksewall@vt.edu*
Multimodal signal processing: how do female songbirds prioritize song and plumage cues?
Research in animal communication often examines receivers' responses to unimodal signals — signals that are transmitted and received through only one sensory channel. However, receivers are regularly exposed to multimodal signals - signals that are transmitted and received concurrently through two or more sensory channels, such as song and plumage color in birds. Behavioral responses may vary among individuals as a function of how they integrate and prioritize signals from different modalities. To determine how variation in the mechanisms underlying signal processing contributes to variation among receiver responses to signals, we examined receiver responses to compound plumage color and song quality signals in female house finches. Specifically, we were interested in whether plumage cues influenced neural response to song cues within the auditory forebrain. To determine this, we exposed female house finches (n=47) to a red or yellow male house finch (n=10) coupled with one of 20 pre-recorded house finch songs (categorized as being long and complex or short and simple). We measured the number of contact calls each female gave during presentation and then measured neural activation within three subdivisions of the auditory forebrain using immediate early gene expression. We found a non-significant trend for females exposed to red males and long complex songs to call more. Additionally, neural activity in one region of the auditory forebrain differed with song but not color treatment. These data suggest that females do integrate plumage and song cues but that the auditory forebrain is not centrally involved in the prioritization of multimodal signals.

12-1 SHANKAR, A; HOYVEN CISNEROS, IN; GRAHAM, CH; POWERS, DR*; Stony Brook University, Stony Brook, NY, George Fox University, Newberg, OR, WSL, Birmensdorf, Switzerland; *dpowers@georgefox.edu*
Deep vs Shallow Torpor: Nocturnal Body Temperature Management in Hummingbirds
Torpor (controlled reduction in body temperature and metabolic rate) is a key energy saving strategy for small heterotherms. In hummingbirds, past studies show exclusive use of deep torpor where body temperature declines with ambient temperature down to a species-specific minimum body temperature. Because hummingbirds have among the highest metabolic rates of all vertebrates, and store little body fat during the day, maximizing their energy savings at night by using deep torpor seems an efficient energy management strategy. However, extensive use of deep torpor could have physiological and fitness consequences, and rewarming costs, particularly on cold nights, could reduce net energy savings. Given these potential disadvantages of deep torpor, a shallower form of torpor might be a better energetic strategy in some cases. From a combination of open-flow respirometry measurements and infrared imaging (all under near-natural temperature and light cycles) on 16 hummingbird species in Arizona and the Ecuadorian Andes, we found that some species are capable of using both deep (~30°C surface-temperature depression) and shallow (8-12 °C surface-temperature depression) torpor (sometimes on the same night), while others almost never use deep torpor. When in shallow torpor hummingbirds do not exhibit the immobility that is characteristic of deep torpor, perhaps suggesting that shallow torpor offers some level physiological restoration characteristic of sleep, while continuing to provide some energy savings. Further, the increased responsiveness during shallow torpor could result in more rapid response to potential predators.

P1-263 SHANNON, RP*; LOVE, AC; BOLEK, MG; Oklahoma State University; *shannrp@okstate.edu*
White blood cell differentials of amphibians naturally infected with multiple trypanosome morphotypes
Disease is one of the leading factors contributing to the global decline of amphibians. While diseases such as chytrid fungus and ranavirus have been implicated in amphibian decline, considerably less is known about how blood protozoa, such as trypanosomes, affect amphibian populations. Furthermore, despite the common occurrence of trypanosome infection in amphibian populations, we still know relatively little about how amphibians respond to trypanosome infection. In this study, we characterize differential white blood cell counts—the relative proportion of five different immune cell types in the blood—in four anuran species (*Rana catesbeiana*, *Rana sphenocephala*, *Rana blairi*, *Hyla cinerea*) with and without trypanosomes. Frogs were wild caught and naturally infected with one to four distinct trypanosome morphotypes, differing in size, presence of a free flagellum, and cell motility. Trypanosome species can have multiple morphological stages in their life cycles, however the species associations of amphibian trypanosome morphotypes are not known. In this study, we found differences in white blood cell differentials between infected and uninfected individuals of a given species. For example, trypanosome infection was associated with lowered lymphocyte counts in *R. catesbeiana*, while trypanosome infection was associated with lowered neutrophil counts in *R. sphenocephala*. Additionally, white blood cell profiles differed depending on the specific trypanosome morphotypes present. This study helps characterize one of the immunological responses of anuran amphibians to trypanosome infection and provides insight into how blood protozoa interact with their amphibian hosts at an immunological level.

P2-70 SHARP, SL*; BREDA, JR; TODD, KL; Westminster College , Westminster College; *sls1013@westminstercollege.edu*
Identical reproductive behaviors rely on different motor circuits
It is widely known that during electronics design complex circuits are made from standardized components. Many individuals often think biological systems are organized in this same way. It is attractive to hypothesize that homologous neurons should participate in similar circuits to produce homologous behaviors between species. However, differences in neuronal activity of homologous neurons have been observed in shell-less mollusks. This work has shown, in swimming behavior, that homologous neurons form different circuit connections in two closely related species. Despite this, little research has been done on differences in homologous neurons in different species analyzing similar behaviors. This research analyzed the circuits involved in reproductive behavior in two closely related leech species, *Hirudo verbana* and *Macrobdella decora*. Both species respond to a hormone (hirudotocin) by progressing through the same reproductive behaviors. Additionally, both synthesize this hormone in two segmentally repeated neurons called Leydig cells. Furthermore, both species have the same cohort of motor neurons that produce behaviors. We hypothesized that if a species-specific circuit difference existed, we might observe it in different motorneuron activity. We have found that there are significant differences in the reproductive behavioral circuit. Quantifiable differences in motorneuron dynamics include: burst duration, inter-burst interval, burst frequency, and the number of spikes per burst. These results indicate that there is a difference in neuronal participation between the two species when producing the same reproductive behavior. The outcome of this research raises a question as to why evolutionarily two closely related species producing the same behavior do so using different circuitry.

60-2 SHARPE, S. L.*; UNGERER, M.C.; NIPPERT, J.B.; Kansas State University, choose title; *sharpes@ksu.edu*

Effects of Drought Stress Across Population and Life Stage in Wild Foxtail Millet Setaria viridis

Drought is a major source of abiotic stress for plants, and poses an increasing threat to conservation, economic activities, and agriculture as climate change increases the stochasticity of precipitation events worldwide. Drought tolerance varies widely in the plant kingdom, both between species and across differently adapted populations within species. Water stress leads to decreased photosynthetic capacity, and can diminish vegetative growth and reproductive allocation, both of which have serious consequences for agricultural and bio-energy crops. Previous work has shown that the effects of drought stress also vary across different life stages. My research examines the physiological and transcriptomic responses to water limitation across life stages in the wild foxtail millet, *Setaria viridis*, a close relative of the agriculturally important foxtail millet, *Setaria italica*. In a drought stress experiment using 9 *S. viridis* populations from diverse geographical locations, population significantly influenced the number of days that plants took to reach a photosynthetic rate of zero. Flowering was found to be negatively correlated with drought tolerance. Further experiments will compare photosynthetic capacity, chlorophyll fluorescence levels, flowering time, seed production, and gene expression patterns in differently adapted populations of *S. viridis* exposed to drought stress at three different life stages (pre-reproductive, bud-stage, and flowering). This research will help elucidate the effects of population adaptation and life stage on drought stress response in a close relative of an important agricultural crop.

P2-258 SHEEHAN, MJ*; FISH, FE; ADAMS, DS; TENNETT, KA; GOUGH, WT; West Chester Univ., Stanford Univ.; *ffish@wcupa.edu*

A 60/40 Split: Differential Weight Support in Dogs

Tetrapod mammals must distribute their weight between fore and hind legs when standing. The proportion of weight by each couplet can vary with species. An elephant carries 55% of its weight on its fore legs, but a monkey has only 44%. There has been no systematic study of weight distribution to determine if the proportion of supported weight on the fore and hind limbs is dependent on body size. Over a four year period, 595 dogs from 123 breeds ranging in size from Chihuahua to Saint Bernard were measured at the Kennel Club of Philadelphia's National Dog Show. Each dog was weighed on a digital scale while standing in a show position alternating fore leg and hind leg support. The overall mean proportion of weight on the fore legs to the total weight was 60.4+4.8% (range: 40.3-78.3) with a fore leg to hind leg ratio of approximately 60/40. When separated into AKC categories, only the working group (e.g., Newfoundland, Rottweiler) was significantly above the 60.4% mean. Using the genetic groups by Parker et al. (2017), dogs with large heads were significantly greater than the mean (e.g., bulldog, mastiff), while herders and coursers (e.g., sight hounds) were lower. The genetic groups sorted by von Holdt et al. (2010) indicated that the group containing only retrievers, mastiff-like dogs, and small terriers were significantly greater than the mean. Using AKC-related categories from von Holdt, mastiff-like dogs were significant greater and sight hounds were lower than the mean proportion of weight supported by the fore limbs. The weight of the head, chest, and musculature for propulsion and braking could explain the greater weight supported by the fore limbs. Despite differences in morphology and size, dogs generally display a consistent differential between fore leg and hind leg support.

P1-20 SHEHAJ , A*; RIMKUS , B; KONOW, N; UMass Lowell; *andrea_shehaj@student.uml.edu*

Differences in Stress-strain and Power-velocity Properties between Muscles with Distinct Fiber Type Composition, Architecture and Mechanical Function

Antagonist muscles with differences in fiber type composition, architecture and mechanical function provide useful models in comparative vertebrate muscle physiology. We have developed a framework to evaluate the physiological performance (length-tension, force-velocity-power) for different muscles within a given individual. Here, we compare active and passive stress-strain, as well as power-velocity properties for TA, a fast-twitch, and relatively pennate-fibered muscle, to SOL, a slow-twitch parallel-fibered muscle in the mouse (n = 4). We test the ideas that parallel-fibered muscle is more compliant and capable of retaining near-maximal force and power production across broader ranges of strain and speed than pennate muscle. Our results show that SOL has significantly more passive compliance than TA, a difference we expect can be explained by different titin isoforms in the two muscles. SOL also has a broader stress-strain curve ($\Delta\varepsilon$ = 29% ± 7%), than TA ($\Delta\varepsilon$ = 12% ± 2%). The differences in stress-strain are reflected in the power-velocity properties with SOL having the broadest power curve: At 2.5 $L_o\ s^{-1}$, SOL retains 87% ± 5% peak power and TA only 56% ± 4%. Our results support the idea that parallel-fibered muscles retain force and power output over greater operating strains and speeds compared to pennate muscles. These differences likely have important implications on muscle mechanical function during movement. Going forward, similar comparisons between muscles from the same individual will allow us to determine the effects of diet and eccentric injury on muscle mechanical function.

44-1 SHEPHARD, AM*; SNELL-ROOD, EC; Univ. of Minnesota; *sheph095@umn.edu*

Costs of adaptive plastic responses to stressors: genetic variation in hormetic responses to heavy metals in a butterfly

Organisms today face a range of stressful environments unknown in their evolutionary pasts. Understanding the mechanisms that promote population survival in novel environments is important not only for providing insight into how organisms may adapt to rapidly shifting anthropogenic environments, but also how organisms have adapted to past changes. One form of phenotypic plasticity, known as hormesis, might play a key role in facilitating organismal survival in novel environments. Hormesis is a phenomenon where exposure to low levels of stress in early life induce developmental changes that prime the organism to better tolerate subsequent stress exposure later in life. Evidence for hormesis is widespread, and such effects have been reported in diverse taxa in response to hundreds of stressors (e.g., chemical stress, temperature, and ionizing radiation). While the benefits of hormesis are clear, its pervasiveness raises an important question: why are hormetic responses not produced all the time but instead require a sensitizing stress exposure to occur? I conducted a multiple-family experiment rearing cabbage white butterflies (Pieris rapae) across a broad range of dietary zinc doses to test whether families with greater hormetic responses to zinc face a tradeoff with fecundity under control conditions - in other words, the ability to mount a hormetic response is itself costly. Preliminary results indicate genetic variation for survival, development time and body size on zinc-dosed diets with some families showing apparent hormetic (i.e., positive) responses to low zinc doses. This work will inform models of plastic and evolutionary rescue, theory on costs of plasticity, and emerging observations on costs of hormesis.

P2-233 SHEPHERD, RM*; EMBERTS, Z; ST. MARY, CM; MILLER, CW; University of Florida, 1999; *r.shepherd@ufl.edu*

The Evolution of Defensive Displays in Leaf-footed Bugs

Many organisms use defensive displays to escape predators. Such displays have both visual and behavioral components that operate in concert. A great example is the startling display of mountain katydids. There have been two hypotheses put forward to explain how defensive displays evolve, the startle-first hypothesis and the defense-first hypothesis. The startle-first hypothesis proposes that the behavioral component evolves first, and is subsequently complemented with a visual component. Alternatively, the defense-first hypothesis proposes that the visual component of the deimatic display evolves first, and is then concealed. In our study, we evaluated these two hypotheses by investigating the evolution of the visual and behavioral components of a deimatic display in leaf-footed bugs (Insecta: Hemiptera: Coreidae). Preliminary phylogenetic comparative analyses suggest that the behavioral component of the deimatic display predates the morphological component. Moreover, the morphological component has independently evolved multiple times and larger species are more likely to possess both components.

P3-70 SHERIDAN, NE*; SEYOUM, S; TITUS, BM; DALY, M; SCHREY, A; RICHARDS, C; Univ. of South Florida, Tampa, Florida Fish and Wildlife Consv. Comm., St. Petersburg, The American Museum of Natural History, New York, The Ohio State Univ., Columbus, Georgia Southern Univ., Savannah; *nsherida@mail.usf.edu*

Genetic Differentiation in the Giant Caribbean Sea Anemone Condylactis gigantea in Florida, U.S.

Condylactis gigantea is an ecologically important member of benthic habitats in Florida. It serves as a host to many species, including cleaner shrimp, and is recognized by many reef fishes as a cleaning station indicator. This phenotypically diverse anemone is considered a single species throughout the Tropical Western Atlantic, but the genetic population structure has not been examined throughout most of its range. Investigating structure may reveal subdivided populations that could be evolving independently. Therefore, to assess structure, we collected tentacle samples from 250 individuals at 7 locations and used restriction site associated DNA sequencing (RADseq) as well as nuclear and mitochondrial DNA sequencing. Initial analyses of the RADseq data suggest two clusters with partial geographic partitioning and some admixture. Individuals in the Dry Tortugas, Upper Florida Keys, and Biscayne Bay were genetically differentiated from individuals in the Lower Florida Keys. The two clusters co-occur in the eastern Gulf of Mexico, west of Key West, and the Middle Florida Keys. Mitochondrial DNA sequences were invariant. Ribosomal DNA (rDNA) analysis supports two clusters with admixture, but not similar geographic partitioning. Here, we detected two clusters co-occurring in all locations, which is concordant with prior results from Jamaica. The discordance between the results could be due to a more robust signal provided by the large number of RADseq loci compared to the rDNA.

S7-9 SHERRATT, E*; SANDERS, KL; The University of Adelaide, Australia; *emma.sherratt@adelaide.edu.au*

Tiny heads: the evolution of microcephalic sea snakes

Snakes exhibit a diverse array of body sizes and shapes, contrary to common belief that they have a simplified body plan. Among living snakes, arguably the most extreme shape changes along the pre-cloacal body axis are seen in fully aquatic sea snakes (Hydrophiinae) in the genera *Microcephalophis* and *Hydrophis*. These ‘microcephalic' sea snakes have tiny heads and dramatically reduced forebody girths that can be less than a third of their hindbody girths. Previously we have shown that this morphology has evolved multiple times in species that specialise on hunting eels in burrows. Furthermore, our research has attributed this variation to evolutionary changes in vertebral patterning during embryo development and divergence in postnatal somatic growth patterns. Yet to be examined is what happens to the morphology of the heads of these so-called microcephalic species. Here we use micro-CT reconstructions of skulls and geometric morphometric methods to characterise skull shape variation in sea snakes. Examining neonate, juvenile and adult snakes across ~40 species, we show that microcephalic species not only have a reduced head size, but their skull shape is most similar to young individuals of regular *Hydrophis* sea snakes. Microcephaly thus appears to have evolved by heterochronic processes, with the skull resembling a neotenic form. Our findings suggest that convergent evolution of microcephalic sea snakes has evolved through external selection pressures acting on developmental pathways, such that through shifts in growth and timing, dramatic morphologies can repeatedly evolve.

P2-24 SHIN, SH*; SARWAR, PF; CHENG, C; SUZUKI, Y; Wellesley College; *sshin6@wellesley.edu*

The role of Ventral veins lacking in endocrine gland development and molting

Hormones are necessary for the proper growth and development of multicellular organisms. However, the development of endocrine glands and transcriptional regulation of hormone biosynthesis remain elusive. Recent studies have demonstrated that the POU transcription factor, Ventral veins lacking (Vvl), plays a major role in ecdysone and juvenile hormone production in several holometabolous insects. In this project, we explored the roles of Vvl in the flour beetle, *Tribolium castaneum*, and the milkweed bug, *Oncopeltus fasciatus*, and examined the potential mechanism by which Vvl regulates hormone biosynthesis. Knockdown of Vvl prevented molting in both species and *vvl* expression was found in the prothoracic glands of both species. Our current efforts are directed towards investigating the mechanism of gland development in *Tribolium* and possible interactions with other major signaling pathways. Given that POU factors also play major endocrine roles in vertebrates, regulation of endocrine processes may share deep homology.

S11-4 SHINGLETON, AW; Univ. of Illinois at Chicago; *ashingle@uic.edu*

Which line to follow? The utility of different line-fitting methods to capture the mechanism of morphological scaling

Bivariate morphological scaling relationships describe how the size of two traits co-varies among adults in a population. In as much as body shape is reflected by the relative size of various traits within the body, morphological scaling relationships capture how body shape varies with size, and therefore have been used widely as descriptors of morphological variation within and among species. Despite their extensive use, there is continuing discussion over which line-fitting method should be used to describe linear morphological scaling relationships. Here I argue that the 'best' line-fitting method is the one that most accurately captures the proximate developmental mechanisms that generate scaling relationships. Using mathematical modeling, I show that the 'best' line-fitting method depends on the pattern of variation among individuals in the developmental mechanisms that regulate trait size, and the morphological variation this pattern of developmental variation produces. For *Drosophila* traits, this pattern of variation indicates that major axis regression is the best line-fitting method. For morphological traits in other animals, however, other line-fitting methods may be more accurate. I provide a simple web-based application for researchers to explore how different line-fitting methods perform on their own morphological data.

P2-142 SHIRLEY, K*; OSBORN, A; CHAMBERS, C; AMBROSE, A; MARKLAND, S; TWOMBLY ELLIS, J; GONZALEZ, VH; KANTSA, A; PETANIDOU, T; TSCHEULIN, T; BARTHELL, JF; HRANITZ, JM; Colorado College, The College of New Jersey, Univ. of Kansas, Savannah State Univ., Oklahoma State Univ., Cornell Univ., Univ. of Kansas, Univ. of the Aegean, Univ. of Central Oklahoma, Bloomsburg Univ. of Pa; *jhranitz@bloomu.edu*

A Plant-Pollinator Network in a Coastal Agricultural Field on Lesvos Island, Greece

Plant-Pollinator (p-p) networks describe ecological services essential to ecosystem function. Because climate change poses severe threats, especially where environmental extremes will be intensified, we studied a p-p network in a post-harvest, agricultural field on the coastal plain of Lesvos Island where low-lying coastal habitats are susceptible to thermal stress and saltwater intrusion. P-p network studies reveal species relationships in communities useful to conservation efforts. We conducted field surveys in July 2018 at two transects within 100 M of the shoreline. We collected insect pollinators and recorded p-p combinations daily. Insects and plants were identified to lowest taxon and analyzed in a network. The network consisted of 57 pollinator and 12 plant species distributed within six modules, i.e. groups of interacting species that are more tightly connected to each other than with the rest of the network. Pollinator services indices were generally low to moderate, with the most variation in the Diptera and Hymenoptera. Modules within the p-p network were distinct. Most pollinators in modules were peripherals, i.e. extreme specialists (86.0%), with some (12.3%) connectors (species connecting modules), only one module hub (1.7%). No pollinator was a network hub. The pollinator community seemed to be mainly comprised of generalist species that interacted with many other species in the community and are not tightly linked in a strong modularity structure.

P1-287 SHISHKOV, O*; JOHNSON, C; HU, M; HU, DL; Georgia Institute of Technology; *olga.shishkov@gatech.edu*

Feeding Fly Larvae Form a Fountain

Black solder fly larvae are edible maggots that are raised by startups all over the world as a source of sustainable protein. A larva competes with its thousands of neighbors to eat twice its body weight per day in decomposing organic waste. We investigate how the collective motion of an aggregation of larvae "pumps" larvae towards a piece of food by considering the feeding behaviors of larvae from individuals to groups of 60,000. We perform time-lapse photography and particle image velocimetry analysis of top and bottom side views of larvae in glass dishes. Around food, larvae from a fountain with their bodies where larvae crawl towards food through the middle of the fountain and fall down the sides once they are done eating. This distributes food between the individuals in the fountain, rather than only allowing a select few larvae to eat.

P2-88 SHOR, EK*; FREEMAN, DA; Univ. of Memphis; *ekshor@memphis.edu*

Brain Sites Mediating Melatonin Regulation of Immune Function and Stress in Siberian Hamsters (Phodopus sungorus)

Siberian hamsters (*Phodopus sungorus*) exhibit robust seasonal rhythms in immune function and stress responsiveness. The environmental cue driving these seasonal adjustments is photoperiod, which is encoded endogenously by the duration of rhythmic pineal melatonin (Mel) secretion. The central neuroendocrine targets mediating Mel-dependent regulation of stress responsiveness and immune function remain unspecified. There are multiple neural Mel targets in Siberian hamsters, including the suprachiasmatic nucleus (SCN), the nucleus reuniens (NRe), and the paraventricular nucleus of the thalamus (PVt). The PVt is of particular interest with regard to stress and immunity as it has been implicated in the neural regulation of the stress response. To address the role of the PVt in seasonal alterations of these measures, male Siberian hamsters underwent PVt ablation or sham ablation. Animals from each group were then exposed to either short- or long-day light cycles. On Week 5 post-ablation, blood samples were collected and used to perform a white blood cell (WBC) count and differential, and a bactericidal capacity assay. On Week 7, animals were exposed to a restraint stress test, during which blood samples were collected and used to perform a WBC count and differential, and a cortisol EIA. Results indicate that the PVt is necessary for the expression of the short-day bactericidal phenotype. PVt status also impacted WBC differential. In addition, these results will be considered in the context of ongoing hormone assays for circulating cortisol. These findings implicate the PVt in mediating seasonal regulation of immunity and stress responsiveness.

83-4 SHORT, CA*; HAHN, DA; University of Florida; *cashort@ufl.edu*
How Do Flies Sense Their Protein Stores? Hexamerin Proteins and Reproductive Behavior in the Caribfly, Anastrepha suspensa
Adequate nutritional stores are a prerequisite for the initiation of reproductive behavior, particularly the competitive, energetically demanding behavior exhibited in tephritid fruit fly leks. Absence of protein in the adult diet can delay male lekking behavior. To coordinate reproductive behavior with nutritional stores, animals must have mechanisms to measure their nutritional stores. While hormones have been implicated in signaling stored carbohydrate and fat in both vertebrates and insects, the mechanisms indicating stored protein remain unknown. However, the fat body has been implicated in communicating amino acid feeding in insects. One potential indicator of protein nutritional status is the hexamerins, a family of proteins secreted by the fat body that can act as an amino acid store. We hypothesized that adult male Caribbean fruit flies, *Anastrepha suspensa*, fed protein will accumulate LSP-2 faster and begin calling behavior earlier than males without protein in the adult diet. Male *A. suspensa* were raised with and without protein in the adult diet, assayed for calling behavior, and then qRT-PCR and western blotting were used to measure LSP-2 transcript and protein abundance. We found that protein feeding increases LSP-2 transcript and protein abundance in *A. suspensa* adult males. Protein feeding also advances the onset and increases the frequency of male calling behavior. Post hoc analysis suggests that LSP-2 titers are not elevated directly after calling behavior, but LSP-2 may stimulating the development of reproductive tissues, allowing reproductive behavior to proceed. Overall, my results suggest that circulating LSP-2 coordinates protein stores with reproductive behavior in *A. suspensa* males, supporting a more general role for LSP-2 in sensing protein status in flies.

P2-33 SHORT, L.J.*; JOHNSON, D.H.; WRIGHT, M.A.; DEEMER, G.A.; MACKAY, S.B.; BERGMAN, D.A.; Grand Valley State University, Grand Valley State University , Grand Valley State University ; *short.lindsey3@gmail.com*
Olfactory Alarm Signaling in Crayfish
Chemical signaling among freshwater animals has been studied to provide insight into the functions of complex predator-prey relationships. A subset of chemical signaling systems is the alarm pheromone, which is typically released when an animal is threatened or has been injured. Crayfish are an integral part of the freshwater food web and utilize chemical communication in many capacities ranging from aggression to reproduction. Crayfish are also hypothesized to release alarm chemicals which elicit a negative or flight response in other crayfish. Our study compared the behavioral responses of *Orconectes propinquus* crayfish using three odorants: a crushed conspecific crayfish, food and predator (*Trachemys spp.* turtle). We hypothesize that subjects will be repelled from the crushed conspecific crayfish and predator odors due to the presence of an alarm odor, whereas food odorants will be attractive. Furthermore, it is expected that crayfish will prefer neutral territory in the maze or spend more time in the non-odor arm when presented with an alarm/stress signal.

P1-208 SHUMAN, JL*; THOMAS, LN; COVI, JA; Univ. of North Carolina, Wilmington; *jacieshuman@gmail.com*
The forgotten trophic child: zooplankton and the management of eutrophic lakes
The current procedures for monitoring of water quality across the state of North Carolina (NC) are incomplete due to the exclusion of both active and dormant zooplankton as measured variables. Jordan Lake, NC, is a reservoir that supplies drinking water to over 500,000 residents and is also important for both flood control and recreation. In 2003, Jordan Lake was placed on the NC 303d list of impaired waters, because of eutrophication. Algal blooms occur on a nearly annual basis in Jordan Lake and these blooms include potentially harmful algal species that produce quantifiable toxin levels. To better understand the reservoir dynamics that allow for these potentially harmful algal blooms, water chemistry variables have been monitored for nine years as part of the NC Ambient Lakes Monitoring Program. Zooplankton, however, are ignored. Zooplankton are an important trophic link in freshwater ecosystems, as they graze on the algae while being the predominant food source of most juvenile fish. The present study connects the water chemistry variables used to assess ecosystem health with the abundance and biodiversity of the zooplankton community. Managers could potentially predict what is happening to the zooplankton community by using the connection between the measured water variables and the zooplankton measurements of abundance and biodiversity. Preliminary data suggest that zooplankton density is positively correlated with trophic status in cooler months. However, during the summer zooplankton density is inhibited by elevated temperatures regardless of trophic status. A spatial and temporal analysis will be presented.

57-2 SIA, T*; ADHIKARI, H; DAVIDSON, B; Swarthmore College; *tsia1@swarthmore.edu*
Mitotic rounding influences fate specification
Dividing cells tend to round up through a loss of adhesion accompanied by increased intracellular tension. This process of mitotic rounding has a well characterized role in proper chromosome and spindle alignment. However, the potential impact of this process on cell signaling and fate specification has not been investigated. We study the impact of mitosis on cell signaling in the the invertebrate chordate, Ciona robusta. During Ciona development, four heart founder cells undergo an asymmetric division each giving rise to a tail muscle progenitor and a heart progenitor. Previous research has shown that the induction of the heart progenitor is caused by the polarized, mitotic redistribution of fibroblast growth factor receptors (FGFR) onto the adherent ventral membrane. In this study, we investigated the role of mitotic rounding in FGFR redistribution. To inhibit mitotic rounding, we employed 5-(N-Ethyl-N-isopropyl)amiloride (EIPA), a selective blocker of a Na+/H+ exchange pump. We found that application of EIPA just prior to founder cell division led to the expansion of the adherent membrane domain and depolarization of FGFR redistribution. Our results suggest that mitotic rounding can impact trafficking of membrane proteins including key signaling components, thereby influencing cell fate specification.

P1-47 SIENKIEWICZ, R; BILLINGS, M; KENNEDY, JH; FISH, FE; GOLDBOGEN, JA; POTVIN, J*; Saint Louis University, Chaminade College Preparatory High School, West Chester University, Hopkins Marine Station - Stanford University; *potvinj@slu.edu*

Evaluating Airship Drag as a Predictor of Baleen Whale Drag

Baleen whales (Mysticeti) are a group of marine mammals that travel across oceanic basins in order to migrate between foraging areas and breeding grounds, thereby incurring high total energetic expenditures. These costs are minimized, mostly by a high degree of body streamlining which enables efficient, low-drag locomotion. Calculating the latter becomes a crucial element towards understanding the larger story of metabolic locomotor costs. As cetacean propulsion can be characterized by swimming modes ranging from carangiform to thunniform, drag generation is decoupled from propulsion by the flukes (Fish & Rohr 1999) and allows the evaluation of low-swim speed drag coefficients from rigid body steady-state hydrodynamics. Over the past decades (e.g. Webb 1975, Kooyman 1989), calculations of the drag generated by baleen whales and their sister taxon (Odontoceti) have used a correlation based on tunnel test data collected on blimps and airships (Hoerner 1962). We have used Computational Fluid Dynamics (CFD) to revisit - and re-confirm - Hoerner's old equation relating drag coefficient to body length-to-width ratio, by using digital reconstructions of the HMA R100 airship of the late 1920's, along with other profiles of differing fineness ratio (3 to 36). A comparison of these results was also carried out with CFD data of (gliding) rorqual drag, and showed agreement within 20% over the fineness ratios found in the field. The differences are traced from the enhanced pressure drag generated by the details of rorqual body shape, including those of the head and tail taper among other features.

P2-95 SIMONITIS, LE*; MARSHALL, CD; Texas A&M University at Galveston; *laureneve@live.com*

Preliminary Data on the Effects of Ink on Shark Swimming Behavior

Inking is a dramatic predator defense system that has interesting neuroecological relevance. When ink is used as a predatory defense, it affects predators visually (as a smoke screen) and chemically (as a deterrent), which may be used to disrupt the reception of chemicals or by being aversive to the predators. However, the physiological mechanisms of ink as a deterrent are still poorly understood. The use of ink as a defense is known for a variety of animals such as: sea hares, cephalopods, and even whales. To determine how ink acts as a chemical deterrent, ink from California sea hares (*Aplysia californica*), common cuttlefish (*Sepia officinalis*) and pygmy sperm whales (*Kogia breviceps*) were introduced into the path of free swimming bonnethead sharks (*Sphyrna tiburo*). Bonnethead sharks are abundant in local waters, are well suited for captivity, and have broad cephalofoils that provide easy access to their olfactory systems. Moreover, the olfactory system of bonnethead sharks is well known, allowing us to further test this sensory system to provide answers regarding the antipredatory function of ink. Sharks were individually placed in a circular mesocosm with a camera mounted overhead. Locomotory kinematic variables (e.g., swimming path, turning radius, angular velocity, etc.) were recorded in response to each of the experimental treatments: the three inks, food odor, food coloring, and sea water. Kinematic variables were used to test the hypothesis that ink negatively impacts swimming behavior. Preliminary data shows sharks change their swimming pattern upon introduction of ink into the water. This reaction confirms that ink negatively impacts shark swimming behavior and supports the hypothesis that ink is used as a deterrent. Future studies will address the ability of ink to deter a predation event and the electrophysiological reaction of shark olfactory systems to ink

133-8 SIMPSON, JS*; LENKER, KL; WILSON, CA; EJOTRE, I; KURPIERS, L; REEDER, D; FIELD, KA; Bucknell University; *jss052@bucknell.edu*

Using transcriptomics to identify patterns of gene expression associated with disease transmission in African fruit bats (Epomophorus labiatus)

Although bats appear to be reservoir hosts for many diseases including zoonoses, how they respond immunologically to these pathogens without succumbing to them is poorly understood. This can pose a challenge when attempting to predict spillover to humans, with the ultimate goal aimed at disease prevention. Comparing factors such as the environment, proximity to humans, reproductive stage, and diet, to certain gene expression profiles, especially focusing on immune genes can assist in further identification of spillover dynamics. For this pilot study, transcriptomic gene expression analysis was used with spleen tissue from eight African fruit bats *(Epomophorus labiatus)*, comparing expression between pregnant and non-pregnant bats. RNA was isolated from samples collected in sub-Saharan Africa and next generation sequencing was performed. We then analysed differential gene expression using a de novo transcriptome assembly with DRAP, pseudo-alignment with Salmon, and differential expression analysis with DESeq2. Although pregnancy has generally been considered a period of immune compromise in mammals, preliminary results showed pregnancy was not the primary variable determining variation in gene expression in these bats. We identified 251 differentially expressed transcripts using an FDR cutoff of 0.05. Some of these genes appear to function in immune responses and may contribute to disease spread. Further investigation with larger sample sizes, compared across multiple covariates, and including samples during various seasons will enhance the knowledge of bat immune responses in regards to their ability to be reservoir hosts. This information can aid in prevention of disease, as bats and humans continuously interact.

P1-119 SIMPSON, RK*; MCGRAW, KJ; DOUCET, SM; University of Windsor, Arizona State University; *rksimpson9@gmail.com*

The Evolution of Complex Courtship Traits: Covariation and Interactions between Hummingbird Displays, Feather Structure, and Color Appearance

There is an astonishing diversity of animal signals, and often animals possess multiple signals. Selection will favor signals that can effectively be transmitted through the environment and detected by the receiver; and how multiple signals interact with each other and the environment during use can further influence signal efficacy. Angle-dependent, coloration often co-occurs with behavioral displays and can vary among species, providing an excellent model to study signal interactions. In these signaling systems, the environment and behavioral displays will interact directly with the angle-dependent structures to create the ornament's appearance to the receiver (i.e. color appearance). We tested how interactions between these three factors produce variation in color appearance, and how micro- and nano-structures of angle-dependent ornaments covary among species with behavior, the environment, and color appearance. We tested these hypotheses in "bee" hummingbirds, as nearly all species in this tribe possess a variant of an angle-dependent ornamental throat patch and stereotyped courtship display. We found interspecific variation in feather structure/reflectance, display behaviors, solar-positional environment, and color appearance, and a negative co-evolutionary relationship between properties of the feathers and behaviors. We also found both positive and negative relationships between feather and behavioral properties with color appearance, illustrating the complex evolutionary relationships between these traits. By integrating the study of intricate behavioral displays, specific color production mechanisms, and environment, our results help improve our understanding the diversity of signals and their interactions.

P2-104 SIMPSON, DY *; TELEMECO, R; LANGKILDE, T; SCHWARTZ, TS; Auburn University , California State University, Fresno, Pennsylvania State University; *dys0004@tigermail.auburn.edu*

Contrasting Differential Gene Expression to heat or fire ant envenomation in Sceloporus undulatus

Environmental stressors, such as extreme temperature change, invasive predators, and other disturbances, can negatively affect an organism's performance, survival, growth rate, and ultimately its fitness. The underlying molecular mechanisms of how organisms respond to diverse stressors are still poorly understood. *Sceloporus undulatus*, the eastern fence lizard, has become an ecological model organism for addressing questions in ecophysiology, and life history evolution. Recently we have developed a high-quality reference genome that furthers its utility for investigating molecular and physiological mechanisms. We are interested in understanding how stress responses may vary when an organism is exposed to diverse environmental stressors such as an extreme heat event as predicted by climate change, or attack by an invasive predator such as a fire ant. In this study, we test whether stress response to either acute heat or fire ant attack diverges at the endocrine level (plasma corticosterone levels) or at the gene expression level. We found that male *S. undulatus* (n = 24) who were either exposed to heat (43C) for up to 3 hours or fire ant envenomation (receiving ~10 stings) each had the same response in corticosterone levels, with an increase relative to the control. Liver RNA seq data are being analyzed to test whether the gene expression response to acute heat and fire ant envenomation is also highly similar or is divergent. These results will bring further insight into the similarity of molecular responses to ecologically relevant stressors.

36-3 SINCLAIR, BJ; Western U; *bsincla7@uwo.ca*

Insect cold acclimation: Underlying mechanisms and opportunities for extrapolation

Most insects modify their thermal tolerance in response to environmental cues. We often simulate this in the laboratory with a variety of low temperature treatments, and use these to both draw inferences about the mechanisms underlying cold tolerance and to make predictions about the capacity for cold tolerance in the field. I will discuss the costs and benefits of experimental designs used to induce acclimation responses, and identify several approaches that may improve the ecological relevance of laboratory acclimation studies. I will then synthesise recent -omics-based work from my laboratory and others to explore our understanding of the mechanisms underlying cold acclimation, and the extent to which those studies are supported by physiological, structural, and biochemical data. Finally, I will suggest some ways in which we can use this nascent mechanistic understanding to inform our ability to predict cold tolerance potential in the field.

P1-282 SINGH, A *; KEEFFE, R; BLACKBURN, D; University of Florida; *snakesalot@gmail.com*

Tips and Fits: Tricks to 3D Puzzle Making

Engaging the public and successfully articulating complex ideas about our scientific research are essential for promoting public awareness and support of science. The growing popularity of 3D-printers and CT- scanning have opened new avenues for engaging the public with biodiversity research. Large-scale digitization efforts of museum specimens such as oVert are making 3D models of real specimens widely available via online platforms such as MorphoSource. These models, especially those of skeletons, easily lend themselves to creative outreach opportunities, such as puzzle making. Puzzles are easy to approach, provide hands-on experience, and can demonstrate complex problems in an engaging way. Here we present our process for developing 3D skeletal puzzles from the specimens available at the Florida Museum of Natural History. We explore a selection of specimens, reconstruction practices using VG Studio Max 3.2, printer types, plastic types, coloring, and attachment mechanisms. These newly created puzzles were created for the purpose of presenting easily identifiable homologous structures to the public in hands-on learning activities. Puzzles can be made more complex or simple depending on the learning objectives and the audience. Educators, students, and the general public can freely download these 3D files for printing at home or in the classroom.

P2-195 SINGH, A.*; FABER-HAMMOND, J. J.; RENN, S.C.P.; Reed College; *avehi.singh@gmail.com*

The Effects of Social Rank on the Gut Microbiome of Astatotilapia burtoni

Social dominance hierarchies are a common system of within-group social ranking. Animals occupying subordinate and dominant ranks differ in their access to food and mating opportunities. They thus exhibit differential behavioral and physiological phenotypes associated with stress, nutrient availability and metabolic activity. We sought to evaluate the effects of social rank in male Astatotilapia burtoni on the gut microbiome, a community of microbes intimately involved in host physiological and metabolic processes. We used non-invasive sampling techniques that are novel in this system to track individual changes in microbial communities. Strikingly, we found a lag between microbial community shifts and behavioral and physiological changes associated with rank. Given this, subordinates had higher levels of pathogenic clades and decreased overall community diversity (alpha diversity) while dominants had higher levels of protective clades and increased alpha diversity. The distributions of several differentially abundant operational taxonomic units (OTUs) were correlated with alpha diversity, suggesting that these clades might be involved in structuring the community as a whole. Taken together, our results indicate that behavioral and phenotypic states associated with social rank induce dynamic, population-level shifts in microbiome composition, an effect putatively mediated by the abundances of certain clades. This study is one of the first to evaluate and track the effects of social rank on teleost microbiomes and highlights the need to integrate microbiome-derived effects into studies of behavior.

P1-18 SINGH, K*; HIDALGO, F; VOESENEK, CJ; BERG, O; MüLLER, UK; California State University Fresno, Wageningen University; *umuller@csufresno.edu*

A dynamically scaled mechanical model of a suction feeder based on the traps of the carnivorous plant Utricularia

Dynamically scaled mechanical models are a valuable tool to address bio-fluid-dynamic questions. Here we describe a mechanical model of a suction feeder based on the traps of the carnivorous plant *Utricularia*, commonly known as bladderwort. Bladderwort traps are among the smallest, fastest, and most specialized suction feeders, thus an ideal model system. This combination of small size and extreme speed makes it difficult to study the mechanics of their suction events. Here we present the design of a mechanical suction-feeder that can simulate the entry flows generated by bladderwort traps. We use scaling laws to preserve flow patterns, and experimental and computational data to simply the design. One such simplification is that opening the trap door is effectively instantaneous. Therefore, we can eliminate the door, approximate the mouth as a fixed-diameter aperture, and employ sudden-onset volume-change or pressure histories. Furthermore, the design of the cylinder and piston can be simplified, knowing that the external flow is effectively inviscid. The mechanical model is scaled up in size by a factor of 200 and in time is slowed down by a factor of 1000. The model comprises a constant-diameter cylinder and piston, actuated by a linear motor, submerged in mineral oil. The set-up is optimized for particle image velocimetry to quantify flow and pressure fields. The resulting parameter space maps will allow us to explore the lower size limit of suction feeding.

P1-189 SINGH, H*; FUSE, M; San Francisco State University; *hksingh@mail.sfsu.edu*

Total Hemocyte Populations are Unaffected after X-ray Induced Tissue Damage to Imaginal Discs in the Hornworm, Manduca sexta

Unlike the mammalian immune system, insects rely solely on innate immune responses to fight against pathogens, having evolved various ways to recognize tissue damage and distinguish between "normal" vs "damaged" tissue. Immune cells in insects are called hemocytes that recognize factors released by damaged tissue and respond by either increasing the circulating number through mitosis or by recruiting the already present hemocytes to the damaged site. Previous research shows that *D. melanogaster* responds to wounds and DNA damage by increasing the number of circulating hemocytes between 8-24 hours post tissue damage. We hypothesized that a similar immune response would be seen in the tobacco hornworm, *Manduca sexta*. We induced DNA damage through whole body x-ray irradiation. We counted the number of circulating hemocytes at different time points using two different techniques - manually with a hemocytometer and automated with flow cytometry. We noted that in *M. sexta*, there were no significant changes in the total hemocyte population from 4 to 72 hour post-irradiation. These data suggest that if hemocytes are required during this type of tissue damage, either (i) the amount is small enough not to be noted in the million plus cell population, or (ii) new hemocytes are created which bind to the damaged tissue and are thus not noted within the overall population of circulating hemocytes. Brdu experiments and immunohistochemistry should allow us to assess changes in tissue associated hemocytes at the site of DNA damage.

P2-114 SIRMAN, AE*; KUCERA, AC; KITTILSON, J; HEIDINGER, BJ; North Dakota State University; *aubrey.sirman@ndsu.edu*

Does chronic stress impact insulin-like growth factor signaling in house sparrows?

Animals can respond to environmental stressors through activation of the hypothalamic-pituitary-adrenal (HPA) axis and subsequent release of glucocorticoids. In the short-term, release of glucocorticoids can facilitate survival and escape from immediate threats. However, chronic, long-term activation of the HPA axis and glucocorticoids (GCs) can have detrimental impacts on fitness and senescence. Recent studies have suggested that the HPA axis may be closely linked with insulin/insulin-like signaling (IIS) pathway, a highly conserved endocrine pathway responsible for regulating resource allocation and stress resistance. Previous work has suggested GCs may play a role in regulating growth hormone (GH) and insulin-like growth factor-1 levels (IGF-1), relative to nutritional conditions. However, little is known about the impacts of chronic stress on the IIS pathway. To test the effect of chronic stress on the IIS pathway we captured adult male house sparrows (*Passer domesticus*), brought them into captivity, and randomly assigned them to one of two treatment groups: control and chronic stress. After a period of acclimation, birds in the chronic stress treatment group were exposed to daily rotating stressors for approximately 7 months. Control birds were housed separately and only disturbed during husbandry tasks once a week. At the end of the experiment, liver and pectoralis tissue samples were collected to measure IGF-1, IGF-1 receptor (IGF-1R), IGF-2, and IGF-2 receptor (IGF-2R) gene expression. Baseline and stress-induced corticosterone were measured at 4 separate time points throughout the experiment. We predicted that birds exposed to chronic stress would have reduced IIS signaling than controls. Results will be discussed within the context of life history theory.

78-5 SIROVY, KA*; KELLY, MW; Louisiana State University; *ksirov1@lsu.edu*

Intraspecific variation in the stress response of the Eastern Oyster, Crassostrea virginica, to salinity changes within the northern Gulf of Mexico

Anthropogenic activity is rapidly shifting environmental variables, causing an urgent need to understand how organisms will respond to changing conditions. This is especially important for oysters as they provide essential ecosystem services including water filtration, shoreline stabilization, and habitat for other marine invertebrates. Within the northern Gulf of Mexico, salinity is one of the most important variables impacting *Crassostrea virginica* and is expected to change rapidly over the coming century. Our objective is to improve our understanding of how the eastern oyster will respond to salinity changes by addressing a major gap concerning the potential for local adaptation to drive differential stress responses across populations. Specifically, we will focus on the role of gene expression changes because shifts in gene expression across populations are often crucial for adaptation to an environmental change. To approach this objective, adult oysters were collected from two sites in Louisiana which naturally differ in their salinity regimes. These oysters were placed in common garden conditions, spawned, and the resulting juveniles were outplanted to either a high or low salinity site. After 15 months of exposure, TagSeq was used to measure the gene expression of juveniles from both treatments. We expect that at both sites there will be differentially expressed genes between individuals with different parental origins representing localized responses to salinity stress. We expect this to be most noticeable at the low salinity site, as this represents the most stressful condition. Differentially expressed genes can provide insight into mechanisms underlying population differences in the physiological response to salinity stress.

P1-126 SISTI, AR*; JOHNSON, EL; EARLEY, RL; University of Alabama; *arsisti@crimson.ua.edu*

Maternal effects and the mismatch hypothesis: dietary exposure to endocrine disruptors in mangrove rivulus fish

Introduction of synthetic contaminants to ecosystems challenges organisms to respond to novel pollutants. 17α-ethinylestradiol (EE2) is an endocrine disrupting compound frequently found in wastewater effluent. Even trace concentrations of EE2 can induce significant phenotypic and physiological changes in fish. In wild populations, exposure to EE2 is unlikely to be confined to a single life history stage or generation. We were interested in determining the effects of compound (EE2, nonylphenol, mix) and route of exposure (water, diet, mix) on phenotypic development in juvenile mangrove rivulus (*Kryptolebias marmoratus*). We found that EE2 elicited higher liver vitellogenin (yolk protein) expression than unexposed controls, independent of route. EE2 administered through the diet resulted in fish with smaller gonads and body mass, and larger liver mass. These results suggest that EE2 has greater effects when fish are exposed through their diet than through the water, but that exposure through any route may impair reproductive function. This prompted a study of whether the environment experienced by a mother would impact offspring responses to exposure. We hypothesized that EE2 administration - via maternal exposure only, juvenile exposure only, or both - would impair growth and development compared to unexposed controls. We also hypothesized that the extent to which such impairments manifest will depend on whether juvenile and maternal exposure regimes match or mismatch. Offspring of exposed and unexposed fish were randomly assigned to an exposure environment that either matched or mismatched their mother's. Growth, behavior, liver vitellogenin and gonad steroid receptor gene expression, and reproductive development were quantified. Here we present preliminary findings of that work.

109-7 SKANDALIS, DA*; LUNSFORD, ET; LIAO, JC; Whitney Laboratory for Marine Bioscience, University of Florida; *dimitri.skandalis@whitney.ufl.edu*

Optogenetic dissection of cholinergic and dopaminergic efferent neuron function in the lateral line system of zebrafish suggests a linear microcircuit model

An effective mechanosensory system mitigates sensory overload by discriminating between mechanical signals emanating from the environment and those created by the organism's movements. We study this regulation, termed corollary discharge, in the fish lateral line. We backfill and optogenetically record calcium activity from cholinergic and dopaminergic efferent neurons (transgenic GCaMP6s). Cholinergic efferent activity was tightly synchronised with calcium activity of identified spinal motoneurons but dopaminergic activity was not. This suggests cholinergic neurons are the source of the corollary discharge, and dopaminergic activity has other modulatory actions. This conclusion was supported by photoablation of the cholinergic cell bodies: spontaneous afferent activity is typically partially or completely suppressed during swim bouts, but this effect is greatly diminished with photoablated cholinergic efferents. From a simple model of the function of the hair cell complex, in which efferents act on hair cells to mediate spontaneous afferent excitation, we predict that the information content of an afferent connected to one hair cell in a neuromast should be the same as for an afferent making multiple connections. Intriguingly, optogenetic recording of calcium activity in individual hair cells (GCaMP6s) indicates that in a given neuromast, only a few hair cells are active at a time, and the majority of hair cells may instead act as a reserve pool in case of damage. Thus despite fairly complex wiring patterns and multiple innervating cell types, we propose that the hair cell complex is functionally a relatively straightforward linear microcircuit.

P2-113 SLACK, K. L.*; VANGORDER-BRAID, J.T.; SIRMAN, A.E.; HEIDINGER, B.J.; Mississippi State Universtiy , North Dakota State University ; *kls942@msstate.edu*

Does experimentally elevated stress exposure influence heterophil-lymphocyte ratios in developing chicks?

Most vertebrates respond to environmental and social stressors by increasing glucocorticoid secretion, which is expected to promote survival. However, when individuals are unable to evade stressors they can be exposed to chronically elevated glucocorticoids, which can have several negative long-term effects. One measure that may be a sensitive physiological indicator of chronic stress exposure is leukocyte counts, however this has seldom been experimentally tested. Here we experimentally manipulated chronic stress exposure in developing house sparrow (*Passer domesticus*) chicks and examined the effects on the heterophil to lymphocyte ratio (H:L ratio). After hatching, broods were split, and half of the chicks were randomly assigned to a control or chronic stress treatment. Chicks from both treatments were handled on days 2, 6, and 10 to measure growth. Blood samples were collected on day 10 to measure H:L ratios. Between days 2 and 10, chicks in the chronic stress treatment were also removed from the nest daily and exposed to restraint stress by placing them in a cloth bag for 30 minutes. We predicted that chicks in the chronic stress treatment would have a higher H:L ratio than their siblings in the control treatment. H:L ratios were analyzed blindly with respect to treatment using a compound microscope and were highly repeatable (R=.883, p=<.001). We found that although there was no effect of treatment on growth (F1,30.33=1.61, p=.21), H:L ratios were significantly higher in chicks in the chronic stress treatment than controls (F1,36=11.21, p=<.001). This study suggests that chronic stress increases the H:L ratio and that the H:L ratio may serve as a sensitive, minimally invasive tool to monitor chronic stress in developing chicks.

68-1 SLEBODA, DA*; ROBERTS, TJ; Brown University; *david_sleboda@brown.edu*

The interaction of intracellular fluid and extracellular collagen influences active contractile force in skeletal muscle

Skeletal muscle is a composite of fluid-filled muscle fibers and fibrous connective tissues. Recent evidence suggests that the interaction of incompressible cells and tensile extracellular collagen influences fundamental mechanical behaviors of muscle, such as the development of tension during passive deformation. We hypothesized that similar interactions between fluid and collagen could influence muscle force produced during active contraction. To test this, we applied 5 psi squeezes to isolated bullfrog muscles mid-contraction and measured the effect on force. Muscles were squeezed using a small, rapidly inflatable cuff that surrounded the middle third of the muscle belly. In separate experiments, we measured the effect of squeezing a series of physical models of muscle. Models consisted of fluid-filled latex tubes (representing muscle fibers) reinforced by stiff, helically-wrapped thread (representing extracellular collagen fibers). The angle at which collagen wraps muscle fibers varies as a function of muscle length, and models were built with a range of physiologically realistic wrapping angles to represent muscle at various lengths. Squeezing muscle at short lengths reduced isometric contractile force by as much as -11.8% ± 0.05% (average ± SD at 0.9 L_0), while squeezing muscle at longer lengths had a neutral or slightly positive effect on force (ex. +3.1% ± 0.01% at 1.3 L_0). This pattern was replicated by the physical models, which either decreased or increased force depending on the wrapping angle of their reinforcing fibers. Our results suggest that the distribution and pressure state of fluid within muscle are mechanically important, and that their effect on isometric contractile force depends on the geometry of fibrous collagen in the extracellular matrix.

107-3 SLEE, JS*; MCLAUGHLIN, JS; DeSales University, Penn State University, Lehigh Valley; *Joshua.Slee@desales.edu*
Making it Stick: A CURE Designed to Introduce Students to the Scientific Process and the Host Response to Foreign Materials
Often overlooked in many cell biology laboratory and cell culture courses; suspension cells represent an important aspect of cell biology and cell culture. Most primary cell cultures and cell lines are adherent cells which grow in monolayers on surfaces. However, other cells such as hematopoietic cells, certain tumor cells, and cells of the immune system are suspension cells which are anchorage-independent meaning they grow and divide in solution. THP-1 cells are a commercially available, spontaneously immortalized monocyte-like cell line derived from the peripheral blood of a patient with acute monocytic leukemia. These cells are an excellent model for suspension cell culture, and studies of the immune system. Researchers have used THP-1 cells to study the host response to implantable devices and biomaterials in vitro. Tissue contacting surfaces of implantable materials initiate a host inflammatory response characterized by many events, one of which includes macrophage attachment to the surface, which ultimately leads to degradation and failure of the material. Using the THP-1 adhesion assay embedded in this CURE, students can participate in the scientific process by testing substances which may prevent the host inflammatory response to implantable devices and biomaterials.

P1-166 SLEVIN, MC*; NIEDERHAUSER, JM; ZIADI, P; NOONBURG, EG; ANDERSON, RC; Florida Atlantic University; *mslevin2018@fau.edu*
Linking territory quality to behavioral syndromes in Bachman's sparrow
Behavioral syndromes are suites of correlated behaviors expressed within or across behavioral contexts. For example, individuals that are more aggressive when confronting rivals are often bolder when confronting novelty. We tested for a behavioral syndrome linking aggression and boldness in male Bachman's sparrows (*Peucaea aestivalis*) and asked whether these traits correlate with aspects of territory quality. We predicted that 1) males that were more aggressive in response to rivals would also be bolder when approached by a human, and 2) aggression/boldness would show a positive relationship with territory quality. We studied male sparrows breeding in Jonathan Dickinson State Park, Florida, USA from March - July in 2018. For each male we measured boldness (flight initiation distance) and aggressiveness (proximity to a sparrow decoy and song playback during a simulated territorial intrusion) to test for positive association between these traits. We also mapped each male's territory and assessed various metrics for territory quality. Our analysis involves generalized linear models describing the relationship between behavioral traits (boldness and aggression) and territory characteristics. Our results will add to an understanding of how behavioral traits and their resulting social dynamics shape how individuals sort in a population, with the aim of connecting our results to conservation practices. Because behavioral syndromes can predict how individuals respond to environmental stimuli (e.g., food shortage, increased predation threat), habitat management strategies may favor individuals with certain behavioral syndromes, thus affecting how the population responds to conservation efforts.

102-7 SMALL, TW*; BRIDGE, ES; BEBUS, SE; SCHOECH, SJ; University of Memphis, University of Oklahoma; *tsmall@archbold-station.org*
Free-living, lower stress-responsive Florida scrub-jays (Aphelocoma coerulescens) perform better on an associative learning test
The rapid stress-induced elevation of plasma glucocorticoids (GC) is well documented in a variety of animals, and these elevated GC levels are known to strongly influence behavior, learning and memory. In many species, the magnitude and time course of increased GCs varies greatly among individuals. In Florida scrub-jays, these individual differences are repeatable throughout the adult lifespan, which indicates they are a persistent aspect of the individual's phenotype. These differences are also correlated with behaviors in jays, such as parental care, and are predictive of annual reproductive success and life span. Previous work found that temporarily captive yearling jays varied in their performance on an associative learning test, but these differences were not associated with differences in GC stress-responsiveness. However, the captive conditions could have impacted performance on the test and the performance of the yearlings may not be representative of older jays. To test if the stress-response phenotype of free-living, adult jays covaries with their performance on an associative learning test, we used a *SmartFeeder* design, controlled by radio-frequency identification (RFID) tags, to target specified jays. Four uniquely colored feeders were aligned 3 meters apart within a jay territory; each was programed to feed only one jay at that site. Thus, each jay was "rewarded" by a specific colored feeder which no other jays could use. Feeder positions were reorder once a day for 4 days and each feeder recorded visitations from assigned and unassigned jays. Lower GC stress-responsive jays performed better on the associative learning test, but the patterns of feeder visits suggested that other factors, such as differences in social learning, may contribute to these findings.

P1-238 SMIRNOFF, DS*; GOSLINER, TM; Cal Academy of Sciences; *dsmirnoff@calacademy.org*
More Robust Phylogenetic Data Reveal Cryptic Clade and Species Diversity within the Nudibranch Family Goniodorididae
Much evolutionary, ecological, and biodiversity research depends on an accurate understanding of species relatedness and robust phylogenies. Such an understanding is hindered by lack of observations, sampling, and misidentifications based on morphology alone. The presence of pseudocryptic and cryptic species often complicates this matter further. The addition of molecular characteristics has lead to the reinforcement as well as the restructuring of established systematic relationships. With more than 3,000 named species, nudibranchs are a group of commonly studied, shell-less marine gastropod molluscs; yet many clades remain unstudied. For the nudibranch family Goniodorididae, there has been no comprehensive phylogenetic analysis using molecular data. This study investigates the molecular phylogeny four of this family's major genera: *Goniodoridella*, *Goniodoris*, *Okenia* and *Trapania*. By incorporating partial sequences of the molecular marker 18S into an existing data set of COI, 16S, and H3 sequences, we present several well-supported clades that have profound bearing on the nomenclature of this family. Our analysis confirms *Trapania* as a monophyletic genus, with strong support for biogeographically based clades within the Indo-Pacific, Eastern Pacific, and Atlantic. Contrary to their presumed monophyly, our data reveal confusion among *Goniodoris*, *Goniodoridella*, and *Okenia*. Nomenclature adjustments, identification of cryptic species, and confirmation of new species identification have brought to light previously unknown clades at the genus level. Our results continue to elucidate fundamental evolutionary relationships in the family Goniodorididae and lay a foundation for future evolutionary, ecological and conservation biology research.

15-5 SMITH, K/M*; CHILDRESS, M/J; Clemson University ; *kylie4@clemson.edu*
Ecological Conditions Influencing the Resiliency of Coral Transplants in the Middle Florida Keys
The severe loss of coral cover over the past 30 years has increased reef restoration efforts and many have turned to transplanting coral fragments. However, not all transplants are equally successful and the ecological conditions necessary for transplant resiliency in the face of disturbances are not well understood. To address this lack of knowledge, we combined a long-term reef community census with a study of transplant survival on 15 reefs in the Florida Keys. A total of 276 coral fragments of five species were transplanted and photographed quarterly from June 2013 to June 2018. During this period, two species were exposed to two acute thermal stress events (2014, 2015) and four species endured a category four hurricane (2017). In general, *Siderastrea siderea* showed higher resiliency to bleaching compared to *Porites asteroides*, and the amount of competitive fleshy algae best explained individual variance in the propensity for bleaching. *Porites asteroides*, *Siderastrea radians*, and *Orbicella faveolata* had the highest survival after a physical disturbance with more than 50% of transplants surviving. *Acropora cervicornis* transplants were most susceptible to physical disturbance with only 16% survival. The reef complexity directly surrounding the coral transplant influenced the survival of *A. cervicornis* and *O. faveolata* corals, but not *P. asteroides* or *S. radians* transplants. Local topography and species composition rather than regional characteristics, such as depth and distance to shore, explained more variation in coral resiliency. These results suggest some species are more resilient to thermal stress while others are more resilient to physical disturbance and local conditions may be the best predictors of transplant success.

P3-134 SMITH, EB*; TSUNEKAGE, T; LEVIN, II; Agnes Scott College; *esmith@agnesscott.edu*
Do Barn swallows (Hirundo rustica erythrogaster) leave a signature maculation pattern on their eggs?
Eggshells of many bird species have distinctive maculation patterns that have led biologists to pose a number of adaptive hypotheses. The signature hypothesis proposes that eggshell patterns allow females to recognize their own eggs in the face of inter- and intraspecific brood parasitism. In barn swallows (*Hirundo rustica erythrogaster*), which are colonially nesting passerine birds, 17% of nests are subject to intraspecific brood parasitism. Our research aims to better understand the range of maculation patterns on the surface of barn swallow eggs. We asked whether eggs in the same nest exhibit a "signature" maculation pattern that was quantifiably more similar to the other eggs in the nest than to eggs in other barn swallow nests. We photographed 23 clutches of eggs, and after uniformly filtering all the images, we analyzed the images in SpotEgg and NaturePatternMatch. SpotEgg quantifies many features of an individual egg, including shape of the egg and the color, shape, size, and dispersion of spots, whereas NaturePatternMatch generates similarity scores between eggs. From these data, we could identify how closely an egg resembled another egg within a given set of eggs. Based on a preliminary data set, we found that 31% of eggs matched most highly to other eggs in the nest of origin, and 54% of eggs included an egg from the nest of origin among the top three best matches. Our work revealed substantial variation in egg maculation patterns among barn swallow clutches which may provide evidence for the signature hypothesis.

P2-52 SMITH, TD*; MCBURNEY, DM; REHOREK, SJ; SMITH, Timoth; Slippery Rock University, NEOMED, Slippery Rock Univ; *timothy.smith@sru.edu*
Presence of lipocalin in the vomeronasal gland of primates: a preliminary study.
The enigmatic Harderian gland (HG), an orbital gland, is connected to the vomeronasal organ (VNO: an accessory olfactory organ) via the nasolacrimal duct (NLD) in many tetrapod vertebrates. Though not all three are always present, at least one is found in any given tetrapod clade. When fully connected (snakes and frogs), the secretions of the HG pass though the NLD and into the VNO, presumably to act as a solvent for odorants. In primates and other mammals, the NLD no longer connects to the VNO. Instead, it is reduced to a vertical canal ending in the inferior meatus (e.g., monkeys), or it drains orbital fluids toward the external nose (e.g., lemurs and lorises). Whether the VNO still requires access these fluids (e.g., through the nasopalatine duct) is unclear. Yet, an alternative exists since the VNO has co-opted nearby nasal septal glands into vomeronasal glands. Very little is known about the structure, function or composition of such gland secretions. Tear specific lipocalin (TSL), an antimicrobial binding protein, has been identified in the orbital fluid of various tetrapods. By using immunohistochemical techniques, we found TSL present in the vomeronasal glands of three New World monkeys (marmoset, tamarin and black-headed spider monkey). In strepsirrhine primates, however, the TSL reactivity ranged from light staining (fat-tailed dwarf lemur, ring-tailed lemur, bushbaby and potto) to absent (loris). The precise role of TSL in the vomeronasal system remains to be determined. However, it is striking that TSL reactivity was stronger and more consistent in New World monkeys, all of which lack any route for HG secretions to reach the VNO.

S1-10 SMITH, Stacey D.; University of Colorado-Boulder, CU Boulder; *Stacey.D.Smith@colorado.edu*
Evolutionary trajectories through color space: Hitting the hotspots and minding the gaps
The distribution of phenotypes observed in nature is shaped by interactions among intrinsic factors, such as the architecture of developmental pathways, and external factors, such as the the strength and direction of selection. Flower color offers a powerful system for understanding how developmental constraints affect natural variation given that the wide diversity of colors across angiosperms has evolved by modifications of just a handful of pigment pathways. In this talk I will review the relationship between the structure and regulation of pigment pathways and macroevolutionary patterns of color diversity. Studies across multiple taxa demonstrate that flower color intensity is highly labile and controlled by rapidly evolving transcriptional activators and repressors. By contrast, changes in floral hue can involve coordinated changes in multiple genes and in some cases, multiple pathways. Moreover, the order of these changes appears to be evolutionarily constrained, leading to gaps in the space of possible phenotypes. Although the exact mechanistic basis for these phenotypic gaps remains unclear, a combination of mathematical modeling and experimental manipulations offer a path for probing the boundaries of color space. Overall, these studies of pigmentation may provide a model for understanding how the molecular dynamics of developmental pathways divide the continuous space of possible phenotypes into discrete character states.

11-1 SMITH, KAH*; LEE, ECS; RAINBOW, MJ; Queen's University; *michael.rainbow@queensu.ca*

The relationship between soft tissue function and morphology in the talus during dynamic in vivo activities

The human foot has evolved to facilitate obligate bipedal locomotion. There are many theories but little data on the *in vivo* function of the bones in the foot and how they contribute to efficient bipedal locomotion. For example, the talus serves as the mechanical link between the hindfoot, midfoot, and proximal segments but its *in vivo* function during locomotion has never been non-invasively measured. The purpose of this study was to use a unique dataset of *in vivo* foot bone surfaces in motion to understand how the talus inverts during loading, and then everts during propulsion. The talus is uniquely passive because its motion is dictated by ligament and cartilage contact forces. Three or more tantalum beads were inserted into the talus, calcaneus, tibia, fibula, cuboid, navicular and the first metatarsal. A CT scan was acquired to generate bone surface files and digitize the beads. The beads were then tracked using biplanar videoradiography (250 Hz) during hopping and jogging. Ligaments were modeled using anatomical texts and bony landmarks. We found that the cervical ligament (CL) resists eversion while the anterior tibiotalar part of the deltoid ligament (DLAT) resists inversion. We further examined whether these two ligaments act to balance each other by computing moment arms and ligament elongation. The CL and DLAT had opposite moment arms. The moment vectors were oriented nearly opposite to each other (175+/-2 degrees). Opposing movements elongated these ligaments as well. Coupling this information with rotation axes may enable comparative studies that can infer subtalar and midtarsal function from ligament insertion locations. This information can be further explored to determine how these ligaments may have controlled the talus in early humans leading to a greater understanding of the evolution of bipedal gait in humans.

P1-68 SMITH, LB; ANDERSON, CV; ROBERTS, TJ; LIEBL, AL*; LIEBL, Andrea; University of South Dakota, Brown University; *Andrea.Liebl@usd.edu*

Transcriptome Gene Expression and Muscle Performance in Anolis Lizards

Animal muscles are exceptionally diverse in structure and function as they meet a variety of demands for an individual's survival. Through natural selection, muscles develop to meet these demands. Additionally, however, individual muscles may vary in gene expression to best suit each of their roles in promoting organism survival. *Anolis* lizards display remarkable diversity in terms of number of species, ecotypes, and geographic locations into which they have radiated. Additionally, their muscles have been shown to exhibit variation in performance (e.g., peak contractile velocity) among muscle types. Specifically, the contractile performance of jaw and leg muscles, likely influenced by natural selection because of their use in survival (e.g. to escape predation and to bite prey), have been shown to vary both across and within individuals. However, the differences in the molecular mechanisms underlying the variation of the metabolic and mechanical properties between the jaw and leg muscles are largely unknown. Here, we used RNA-seq to measure gene expression of jaw and leg muscles from *Anolis* lizards. Gene networks have been identified differentiating the two types of muscles. This data may allow us in the future to compare gene expression differences between the muscles with differences in muscle (e.g. twitch time and peak contractile velocity) and whole-organism (e.g. bite force and sprint speed) performance to elucidate the molecular mechanisms that create variation in performance in anoles.

25-6 SMITH, HE*; HOOVER, SR; SALMON, M; SEAMAN, H; COPPENRATH, CM; HIRSCH, S; PERRAULT, JR; Florida Atlantic University, Loggerhead MarineLife Center; *ichthyodea@gmail.com*

Effect of the Fire Ant Pesticide Hydramethylnon (AMDRO®) on the Nest Survival and Hatchling Orientation of Loggerhead Sea Turtles

Invasive fire ants are voracious predators of ground nesting birds and reptiles, and are spreading rapidly throughout tropical and temperate climates. The pesticide AMDRO® has been widely used on marine turtle nesting beaches to protect nests and hatchlings from these predators, but no studies have been done to thoroughly assess its effect on any reptile species. In other vertebrates, contact with AMDRO® can result in visual impairment, dermal abrasions, and reduced reproductive success. In this field study, we examined its impact on hatching success, emergence success, and orientation behavior in loggerhead sea turtles (*Caretta caretta*) in Juno Beach, Florida. Pesticide granules were placed on the sand above the nest days in advance of an emergence; corn grit granules served as the vehicle control and were placed above nests for comparison to the AMDRO® treated nests. Sand samples were collected to determine if the toxicant persisted in the environment, and preliminary analyses indicate that the pesticide remained in the sand after dosing. We found that the toxicant had no effect on hatchling morphology, hatching success, or emergence success. It also had no effect on the ability of hatchlings to orient toward the ocean (a visually mediated response). However, we did notice more ant and crab predators at treatment nests than are normally seen at our study site. Thus, while AMDRO® might not directly impact reproductive success or hatchling behavior, it had the unanticipated effect of possibly increasing nest vulnerability to predators.

P1-22 SMITH, SK*; PHELPS, SM; Univ. of Texas, Austin; *samksmith@utexas.edu*

Vocal Morphology and Elaborate Display Behavior in Singing Mice

Elaborate displays are pervasive across the animal kingdom and although much work has explored their ultimate explanations, less attention has been given to the mechanisms underlying them. How does morphological adaptation enable display elaboration? We examine this question using Alston's singing mouse, *Scotinomys teguina*, a murid rodent that produces a highly elaborate, sexually dimorphic song used in mate attraction and male-male competition. Notes are more rapidly repeated, have a lower frequency, and span a greater frequency range than other rodents' vocalizations. For example, the Northern pygmy mouse, *Baiomys taylori*, belongs to a sister genus and their songs include slower, less dramatic, and entirely ultrasonic frequency modulation. Laboratory mice, *Mus musculus*, make highly frequency modulated notes but in a narrower frequency band and entirely ultrasonic. To examine whether changes in larynx morphology underlie these behavioral differences, we characterize species differences in collagen, elastin, and glycosaminoglycan abundance in the vocal folds using Masson's Trichrome, Verhoeff-Van Gieson, and Alcian Blue stains of laryngeal sections. Initial results show all three species have dense bands of elastin and collagen in deep layers and glycosaminoglycans in superficial layers of the vocal folds. Compared to pygmy mice, *S. teguina* vocal folds seem to exhibit hypertrophy and have a vocal membrane, a structure not present in many rodents, but that has evolved independently in at least four mammalian orders. We are now performing more exhaustive morphometric studies of species differences in larynx structure, along with μCT imaging to relate larynx morphology to other aspects of the vocal and respiratory tracts. This work lays the foundation for understanding what morphological innovations contribute to *S. teguina* song elaboration.

1-3 SMITH-VIDAURRE, G.*; ARAYA-SALAS, M.; WRIGHT, T.F.; New Mexico State University, Cornell Lab of Ornithology, Cornell University ; *gsmithvi@nmsu.edu*

Monk parakeets exhibit strong individual signatures but weak acoustic convergence over higher social scales

Despite a longstanding interest in the evolutionary origins and maintenance of vocal learning, we know little about how sociality influences vocal learning in natural populations. Naturalized populations provide exciting opportunities to study vocal learning as cultural patterns develop in real time. Monk parakeets (*Myiopsitta monachus*) have established naturalized populations across the world through the global pet trade. Naturalized monk parakeets in the United States converge on shared call types at nesting sites, suggesting that learned calls serve to signal group membership. It remains unclear, though, whether such learning processes are a general characteristic of the species or have changed during introduction. We examined patterns of geographic variation in the native range to test the generality of the "signaling group membership" hypothesis across multiple social scales in monk parakeets. We recorded contact calls across 405km in Uruguay. We used spectrographic cross-correlation and random forests to measure acoustic similarity and compared similarity values across social scales and geographic distance using generalized dissimilarity modeling and Mantel tests. We found low acoustic similarity within nesting sites, groups and pairs compared to individuals, and only a weak relationship between acoustic similarity and geographic distance. These results suggest that monk parakeets may not converge on shared contact calls in their native range, in contrast to previous findings with naturalized populations and other parrot species. This study serves as a baseline to ask why vocal learning processes differ among native and naturalized populations, perhaps influenced by social structure during introduction.

P1-210 SMOOT, SC*; ZOHDY, S; SCHWARTZ, TS; WILSON, AE; Auburn University; *scs0051@auburn.edu*

Meta-analysis of publication year and latitude on the Dilution Effect Hypothesis

The Dilution Effect (DE) hypothesis has played a central role in disease ecology as a way to describe the likelihood of zoonotic disease emergence. The DE states that infectious diseases are less likely to emerge in communities with rich biodiversity because more species diversity can act as a buffer, diluting the number of infected individuals and protecting against emerging infections. The objective of this project was to analyze whether the heterogeneity observed in conclusions in DE hypothesis-based research could be explained by moderators like year of publication and latitude. We performed a meta-analysis using a previously published dataset by Civitello et al. 2015 on vertebrate and invertebrate animal systems and excluded plants. Year of publication could explain some of the variation and graphically reflect changes over time. We were particularly interested in investigating whether there were more studies published supporting the DE hypothesis, since its introduction in the year 2000, suggesting publication bias. A total of 101 animal studies were analyzed using Odds Ratio as the effect size to examine the effect of year of publication estimated 0.0608 (SE=0.025) with marked large heterogeneity (I^2=90.30%) using the random effects model. A smaller subset of 25 field studies were used to examine the effect of latitude. We found no significant effect of year of publication or latitude in the smaller data subset. The effect of publication year was significant (p-value = 0.0152) in the full dataset, with an increase in each year more likely to publish research rejecting the DE hypothesis, suggesting potential publication bias in support of the DE hypothesis soon after publication. These results suggest that caution should be taken when implying the DE hypothesis in management decisions based on science conducted more than ten years ago.

P1-172 SNEKSER, JL*; DIESTLER, E; WYNNE, RD; LIU Post, St. Thomas Aquinas College; *jennifer.snekser@liu.edu*

Sex differences in zebrafish shoaling behavior: Are stress and cortisol the underlying proximate mechanism?

Understanding the social behavior of animals involves the integration of ultimate and proximate explanations. Evolutionarily, the social choices made by individuals are vital to their survival and reproduction. The ultimate evolutionary explanations of social behavior have been well-supported by numerous empirical studies: one or more of the animals involved in the social interaction experiences some benefit. Determining the proximate mechanisms of affiliative behaviors are a bit more complex. Cortisol expression has been suggested, as social contact, or the lack thereof, is often associated with the stress response. Interestingly, studies have also indicated significant sex differences in measured cortisol levels. Our goal is to utilize zebrafish (*Danio rerio*) to determine if the expression of social behavior is related to differences in cortisol levels. We have found that while both sexes readily shoal with groups of zebrafish rather than spend time alone, significant sex differences are apparent when examining specific aspects of shoaling choices, related to shoal size and body coloration. We are currently using a water-borne hormone extraction protocol and EIA to determine how these real-time shoal choice behaviors, and the observed sex differences, correlate with endogenous cortisol expression.

24-3 SNOW, JW*; DEORAS, N; MACLEOD, SG; SHIH, SR; JOHNSTON, B; ADAMES, T; Barnard College, Columbia University; *jwsnowch@gmail.com*

Newly Eclosed HoneyBees Have an Immature Heat Shock Response

A highly conserved system of cellular stress responses is involved in maintaining proteostasis, the homeostasis of protein synthesis, folding, function, and degradation, in the face of diverse environmental insults. One branch of this network is mediated by the Heat Shock Response (HSR), which we characterized previously in adult honey bees. In other species characterized to date, aging, both as a function of time and reproductive potential, results in proteome breakdown and a decreasing ability to mount responses by the HSR. By contrast, we found that newly eclosed honey bees have an immature heat shock response compared to older adult bees. The honey bee HSR increases in induction magnitude during transition to nurse and forager stages. This finding represents a first report of a species for which the HSR increases in potential with age. Future work aims at understanding the molecular mechanisms involved in upregulation of HSR capacity with age and placing these findings in the context of the needs of the honey bee colony.

P1-101 SNYDER, N M*; DICKERMAN, L D; REED, W L; North Dakota State Univ., Univ. of Minnesota Duluth; *nicole.snyder@ndsu.edu*

Seasonal trends in nesting physiology of adult Laughing Gulls (Leucophaeus atricilla)

Timing of breeding can be important indicator of offspring phenotype & survival in many regions. Offspring produced later in breeding season typically suffer lower survival. Because strong selection is associated with timing of breeding I expect breeding adults to have evolved mechanisms to respond to cues of season & therefore moderate seasonal cues they give to their offspring. Again, because strong selection exists, I expect offspring to also evolved mechanisms to receive, interpret, & respond to cues from both their mothers & environment. We are providing a tractable system to understand how organisms integrate these cues & communicate environmental information. Birds are often seasonal breeders making good models for exploring seasonal effects on timing of reproduction & development. In seasonal breeders, I hypothesize adults adjust offspring phenotype (i.e. egg shape, size, embryo growth) in accordance to timing of breeding, not solely to adult condition. I hypothesize their offspring integrate cues of season from environment (photoperiod) & mothers (hormones), resulting in seasonally different phenotypes (growth & hatch survival) adaptive for the timing of breeding season. To test these predictions, we monitored a breeding colony of Laughing Gulls (*Leucophaeus atricilla*). We observed nest initiation & egg laying. We trapped adults on observed nests to gather information about the breeding adult's condition & physiology. Further, we collected first-laid eggs across the nesting season & incubated the eggs under experimental photoperiods (14 hr vs. 18 hr of light) to evaluate hatched chick phenotypes. By integrating seasonal information from adult, egg, & chick, we provide insight on the underlying mechanisms evolved to regulate offspring phenotype.

41-3 SOCHA, JJ*; HERNANDEZ, P; OSSENKOPP, S; GRAHAM, M; ZAMORE, S; Virginia Tech, William Fleming High School; *jjsocha@vt.edu*

Tongue-sticking: A static tongue flick in flying snakes

Tongue-flicking in lizards and snakes is used primarily for chemo- and mechanosensation. This behavior is characterized by sweeping, vertical movements of the tongue, with variations that include single bouts or high-frequency oscillations that occur multiple times per second. In previous studies of flying snakes (genus *Chrysopelea*), we observed what appeared to be tongue protrusion without oscillatory flicking, occurring only in the context of locomotion. To investigate this behavior, we studied tongue movements of *Chrysopelea paradisi* during locomotion with a setup designed for gap crossing. This setup consisted of two artificial branches oriented horizontally and suspended 1.5 m above the ground, with a gap of about 21 cm. Two high-speed cameras (Photron APX-RS) were used to record tongue behavior at 200 fps, while a synchronized motion capture system (Vicon) recorded the three-dimensional position of the head. Snakes often exhibited tongue protrusion without vertical movement, a behavior that we term as a ‘tongue-stick'. Specifically, the snake protruded the tongue after entering the gap, and retracted it just prior to reaching the target branch. In between, the tongue remained extended in a static posture as snake translated forward. We also recorded snakes slithering prior to entering the gap, and as a control, across the branches but with the gap closed. Tongue-sticking occurred in both conditions, indicating that this behavior is not restricted to gap crossing. In contrast, tongue-sticking was not observed when snakes were at rest, congruent with informal observations in their lab habitat enclosures. The function of tongue-sticking is unclear, but its association with locomotion suggests a possible non-chemosensory role.

P2-25 SOCKI, FM*; PANHUIS , TM; Ohio Wesleyan University, Delaware; *francesca.socki@gmail.com*

Comparative Histological Investigation of the Ovarian and Placenta Structure in The Viviparous Fish Genus Poeciliopsis

Across the fish genus Poeciliopsis there are varying degrees of placentation, determined by the amount of continued maternal nourishment provided to the embryo after fertilization. This placenta variation can be studied using a morphological approach to examine the placenta structures involved in maternal-fetal nutrient exchange. Possible comparative features include the maternal follicle that surrounds the developing embryo, the amount of yolk present in the yolk sac of embryos, and embryo structures potentially utilized for nutrient absorption. Recent comparative morphological studies in Poeciliopsis have used scanning electron microscopy techniques, finding surface features of the maternal follicle and embryos that vary across species. We present a preliminary histological analysis that compares the gestating ovaries from four different species of Poeciliopsis representing placentation variation. Histological slides were previously prepared from fixed, embedded, sectioned, and hematoxylin and eosin stained gestating ovaries of Poeciliopsis gracilis, P. infans, P. prolifica, and P. turneri. Slides were observed at 40x under light microscopy and digital images were captured using the program Infinity Analyze. We are in the process of creating an extensive digitized collection and panoramic images of entire ovaries. With these panoramas we have begun to grasp a clearer picture of the overall features of the ovary, embryos, maternal tissues and cellular structures. We are currently using these images to determine which ovarian and placenta structures to compare across species. Once determined, future microscopy at higher magnification will enhance our understanding of the evolution of placentation in Poeciliopsis.

P1-83 SOERENSEN, MS*; KORSMEYER, KE; Hawaii Pacific University, Oahu; *msoeren1@my.hpu.edu*

Swimming energetics of coral reef fishes in wave-induced water motion

Reef fishes are often highly site-attached, meaning they are dependent on remaining near particular feeding and refuge sites. It is therefore important for their survival to maintain a specific position on the reef, which represents a challenge in a wave-swept habitat. Consequently, reef fishes have evolved many different swimming modes and physical attributes, which may decrease energy expenditures or improve performance in this challenging environment. However, while field studies have provided evidence of wave-energy shaping the distribution of reef fishes based on these attributes, little is known about their specific swimming and energetic advantages in different levels of wave-induced water flows. In wave-induced water flows in shallow waters, fish are subjected to a bi-directional oscillatory flow, which imposes both rapid changes in water flow velocities and the direction of water flow. However, most experimental studies looking at the energetics of different swimming techniques and morphological attributes of coral reef fishes, have done so in a uni-directional, steady flow. This study used a modified swimming respirometer to examine how the swimming modes of different species perform energetically under both constant steady flow and bi-directional oscillatory flow. The results of this study will determine how the turning and repeated acceleration and deceleration required to hold-station in wave-induced water flow, will affect their energetic cost of swimming in relation to different swimming modes. Furthermore, it may provide an explanation for the observed distribution of fish species with different swimming modes on coral reefs, as observed in field studies.

P2-31 SOKOLOV, E; MARKERT, S; HINZKE, T; SOKOLOVA, IM*; Leibniz Institute for Baltic Sea Research, University of Greifswald, University of Rostock; *inna.sokolova@uni-rostock.de*

Proteomic rearrangements underlie mitochondrial responses to intermittent hypoxia in a hypoxia-tolerant marine bivalve Crassostrea gigas

Oxygen variability represents a major stressor for aerobic organisms, and mitochondria are the main target of hypoxia-reoxygenation (H/R) injury. Many hypoxia-tolerant species such as intertidal bivalves are adapted to frequent and drastic oxygen fluctuations, but the mechanisms allowing their mitochondria to maintain integrity and function under these conditions are not well understood. We investigated the effects of H/R stress (24 h of hypoxia followed by 1 h of recovery) on mitochondrial (phospho-)proteome in an intertidal bivalve, the Pacific oyster *Crassostrea gigas* . Oyster mitochondria showed functional robustness maintaining oxidative phosphorylation capacity and mitochondrial membrane potential during H/R stress. The functional stability of oyster mitochondria associated with rearrangements of mitochondrial proteome and phosphoproteome that started in hypoxia but became considerably more pronounced during reoxygenation. Exposure to H/R stress upregulated mitochondrial electron transport system proteins (most notably Complexes I and IV), suppressed pathways channeling electrons to ubiquinone, stimulated mitochondrial quality control mechanisms and modulated protein synthesis and transport pathways. These shifts in the mitochondrial proteome may play an important role in adaptive responses to intermittent hypoxia in oysters complementing adaptive shifts in anaerobic metabolism and metabolic rate depression.

S6-4 SOKOLOVA, Inna; University of Rostock; *inna.sokolova@uni-rostock.de*

Mitochondrial adaptations to fluctuating oxygen levels in hypoxia-tolerant marine bivalves

Mitochondria play a central role in ATP provisioning, redox and Ca^{2+} homeostasis, cellular signaling and life death decisions of aerobic organisms. Animal mitochondria are extremely sensitive to fluctuating oxygen (O_2) levels such as occur during tissue ischemia and/or environmental hypoxia. In hypoxia-sensitive organisms, hypoxia and especially post-hypoxic reoxygenation cause mitochondrial injury due to the elevated production of reactive oxygen species, Ca^{2+} overload and damage to the mitochondrial membranes and enzymes; yet many hypoxia-tolerant species (including intertidal invertebrates) can endure frequent hypoxia-reoxygenation due to the diurnal and/or tidal O_2 cycles without apparent ill effects on mitochondrial integrity and function. The mechanisms of such exceptional mitochondrial robustness are not yet fully understood. I will discuss the mitochondrial responses to intermittent hypoxia in marine intertidal mollusks emphasizing the potentially adaptive functional and proteomic changes of the mitochondria as well as the modulation of cellular protection and stress response pathways (including antioxidant defense, autophagy and apoptosis) that might contribute to high tolerance to fluctuating O_2 levels in these organisms. I will also discuss the current knowledge gaps with an outlook to future studies needed to shed light on mitochondrial adaptations to frequent oxygen fluctuations and evolution of metabolism in extremely variable environments as well as identify potential targets for future therapies to protect sensitive mammalian tissues from stress-induced injuries (e.g. during ischemia-reperfusion).

48-6 SOLIE, SE*; CAVES, EM; NOWICKI, S; JOHNSEN, S; Duke University; *sarah.solie@duke.edu*

Investigating categorical perception of color in Trinidadian guppies

Signals of male quality often vary continuously, and it is often assumed that signal receivers also perceive these signals continuously. New evidence suggests, however, that some species may perceive continuously variable color stimuli categorically. Categorical perception has been demonstrated in only primates and birds; whether this is a general feature of vertebrate visual systems is unknown. We investigate categorical perception of a color signal in the Trinidadian guppy, *Poecilia reticulata*. Categorical perception requires that animals (1) label signal variants on either side of perceptual boundary as 'similar', and (2) discriminate between stimuli from opposite sides of a category boundary better than equally different stimuli within a category. Guppies were trained on a food-reward protocol in which fish moved colored chips to reach a food reward. Chip colors spanned the yellow to orange range of color variation in natural signals. Fish were presented with a foraging grid comprising ten background chips and two target chips of a different color, with target chips covering a food reward. Fish passed a trial if they located the food reward under the target chips before flipping background chips, indicating that fish could discriminate between target and background colors. To test for category boundaries, we quantified pass frequency for trials in which the background represented the ends of the continuum, and the target chips were colors within the continuum (e.g. 1|2, 1|3, etc. and 8|7, 8|6, etc.). Large jumps in pass-frequency marked potential category boundaries. To determine whether discrimination increases across category boundaries, experiments compared pass frequencies for color pairs within categories, and for equally spaced pairs across category boundaries. Results will contribute to our understanding of the taxonomic distribution of categorical perception of color.

P1-145 SOLIS, GM*; HUSAK, JF; Univ of St. Thomas; *soli8428@stthomas.edu*

Effects of arginine vasotocin and mesotocin on aggression in male Caribbean Anolis lizards

Although testosterone (T) is typically a primary mediator of male aggression in lizards, Caribbean *Anolis* lizards do not all seem to follow the rule of more testosterone-more aggression. We manipulated non-steroid hormones to determine what might mediate behavior in a low-T-high-aggression species (*Anolis sagrei*), as well as to determine whether similar responses would be observed in a high-T-high-aggression species (*A. cristatellus*). Following a 3-week period of acclimation in the laboratory, 17 male *A. sagrei* and 14 male *A. cristatellus* were randomly assigned experimental groups (arginine vasotocin, mesotocin, or saline IP injection), using standard doses. Behavioral responses to a mirror were video-recorded for 20 min after a 15-min acclimation period. Analysis of the responses noted the type(s), frequency and duration of aggressive bouts for each individual. We then compared the experimental groups to the controls before making a comparative analysis between the species. In *A. sagrei*, mesotocin-injected lizards tended to be less aggressive than the other treatments, but much more variable. In *A. cristatellus*, mesotocin-injected lizards also had more variable responses, but they tended to be more aggressive than the other treatments. Our results suggest that more than just T signaling may be responsible for variation in aggression among Caribbean anole species.

P2-224 SOLLA, A*; O'ROURKE, CF; RENN, SCP; Reed College; *sollaau@reed.edu*

Fish Don't Care About Your Gender Assumptions: Genital Morphology of Three Cichlid Fishes

The *Julidochromis* genus of African Rift Lake cichlids provides an excellent opportunity to investigate differences in social role between closely-related taxa. Previous work has been focused on describing the social roles of two species in the genus; *J. marlieri* females are socially and reproductively dominant, whereas *J. transcriptus* females display the reverse social pattern. Based on work done in non-fish systems that showed differences in genitalia based on social role, we performed a morphometric analysis on the genital papillae of both sexes of *J. marlieri* and *J. transcriptus*, to determine if the differences in social roles were reflected in genital morphology. We performed the same analysis on the lekking species *Astatotilapia burtoni*, which was used as an outgroup for taxonomic distance and behavior. *J. marlieri* displayed clear dimorphism between the sexes, while *J. transcriptus* displayed ambiguous genital structures; the strong dimorphism in *J. marlieri* may not be true sex role reversal, but suggests that sexual selection might be occurring within this species. *A. burtoni* genital morphology appeared to change based on position in the social hierarchy. To the best of our knowledge, this is the first time plasticity in external genital papillae has been documented in fish that do not change sex.

25-7 SOMJEE, U*; WOODS, A; DUELL, M; KOHN, G; MILLER, CW; University of Florida, Gainesville, Smithsonian Tropical research Institute; *ummat.s@gmail.com*

The metabolic costs of maintaining a sexually selected weapon

Horns in antelopes, tusks in elephants and antlers in deer are all examples of animal weapons. The largest and most exaggerated of these structures are often used in competition among males for mating opportunities with females. These large structures are predicted to be energetically expensive for animals to maintain and carry. Yet, the costs associated with the metabolic maintenance of these traits for individuals of different sizes remains a major gap in our understanding of positive size scaling. We examine an insect with enlarged hind legs used as weapons in male-male combat. We capitalize on the behavior of this insect, which autotomizes its sexually selected weapon (without regeneration), to isolate the metabolic rate associated with maintenance of these traits. Using flow-through respirometry we measure the aerobic cost of the weapon by measuring CO_2 production rates before and after leg-autotomy. We find that larger males had proportionally larger weapons for their body size, and that larger males also had proportionally higher metabolic rates compared to females or to small males. A sexually selected weapon accounted for a large proportion (23%) of energy expenditure at rest, and metabolic enzyme assays reveal highly metabolically active tissue, suggestive of high metabolic maintenance costs of these weapons. These energetic maintenance costs remain a largely unexplored avenue to understand the forces that shape the positive size allometries of sexually selected weapons so ubiquitous in nature.

30-3 SONDHI, Y*; THEOBALD, J; KAWHARA, AY; Florida International University, Miami, University of Florida, Gainesville, FIU; *yashsondhi@gmail.com*

Evolution of Light Sensing Opsins in Insects

Insects typically have three to five functional opsins responsible for detecting different wavelengths of light and these opsins are essential to see colour. Nocturnal and diurnal insects have vastly different conditions in which their visual system function, both in the amount of background illumination as well as spectral properties of the visual stimuli they need to detect. This results in different selective pressures on their visual genes and quantification of the purifying or diversifying selection acting on different opsins can be used to infer their relative importance for day and night vision. There has been an increase in the number of insect genomes and transcriptomes publicly available and we use these data to examine the evolution of opsins across insect lineages. We use a phylogenetically informed annotation approach to identify opsins and model rates of evolution of opsins and duplication and deletion events. We detect multiple opsin duplications and deletions as well as different rates of sequence evolution between opsins; we also test if this linked to their diel activity period. We find that UV opsins in particular have significantly different rates of selection between some nocturnal and diurnal insects and discuss the possible biological reasons behind the differential rates of selection. We explore some of these ideas such as the effect of light level on colour perception in the UV and the role of UV reflectance in plant-pollinator interactions.

P3-8 SONG, Y*; FULL, R J; DAI, Z; Nanjing Univ. of Aeronautics and Astronautics , Univ. of California, Berkeley; *ysong_cn@berkeley.edu*

Geckos Actively Align Toes against Gravity during Sideways Wall Running

Geckos agilely maneuver on smooth surfaces using millions of tiny foot hairs (setae) that attach via van der Waals interactions. The morphological arrangement of the setae results in toes possessing directional sensitivity generating more force when pulled by the foot. Geckos tend to align their toes more vertically against gravity when racing up walls. We hypothesized that toes represent an opportunity for distributed control, whereby their alignment can be actively adjusted to remain more oriented against the gravity vector as geckos change direction on vertical surfaces. To test the hypothesis, we ran Tokay geckos sideways on a transparent acrylic wall while measuring orientation with high-speed cameras and contact area of the setae using frustrated total internal reflection. We used vertical climbing of the same individual as our control. Sideways wall running geckos aligned the toes of their top fore and hind feet against gravity, more like the toe orientation observed in the front feet during vertical climbing. Contact area was not compromised, but redistributed among toes to generate adequate forces. To further test the hypothesis, we induced slipping and discovered strong passive toe alignment against gravity. We conclude that distributing control among multiple adjustable structures can increase the effectiveness of maneuvers in complex environments.

141-7 SONG, H; Texas A&M University, College Station; *hsong@tamu.edu*
The making of a locust: a closer look at reaction norm evolution
Locusts are grasshoppers belonging to the family Acrididae (Insecta: Orthoptera) that can form dense migrating swarms through an extreme form of density-dependent phenotypic plasticity, in which cryptically colored, shy individuals (solitarious phase) can transform into conspicuously colored, gregarious individuals (gregarious phase) in response to increases in population density. This syndrome of coordinated changes is known as locust phase polyphenism and the two phases that can result from locust phase polyphenism are among the most striking coordinated alternative phenotypes known. While locusts have the most dramatic expressions of density-dependent phenotypic plasticity, recent studies suggest that non-swarming grasshopper species that are phylogenetically close to locusts also show traces of density-dependent phenotypic plasticity. A comparative quantification of density-dependent reaction norms across locusts and non-swarming grasshoppers that belong to the same genus shows that different components of locust phase polyphenism have followed independent evolutionary trajectories and have not evolved in a coordinated fashion. An evolutionary scenario of how locusts have evolved from grasshoppers and how some grasshoppers have lost their ability to swarm is presented in a phylogenetic framework.

91-5 SOTO, A*; MCHENRY, MJ; Univ. of California, Irvine; *alberts2@uci.edu*
The hydrodynamics and control of prey pursuit in zebrafish
A fish predator's survival depends on the ability to chase down prey. Many fish predators move in discrete, burst-and-coast bouts of activity. To understand the biomechanics of active pursuit with intermittent swimming, we conducted predation experiments in zebrafish. Zebrafish accelerated and turned toward their prey during each tail beat. The amount of turning could be predicted by the bearing angle at the end of the previous coast phase and was correlated with the lateral excursion of the tail fin. To investigate the mechanisms of directional control, we developed a biomechanical model that simulates active pursuit. Further, we quantified the forces generated by free swimming fish executing turning maneuvers using a novel particle image velocimetry and motion tracking method. This work provides insight into the biomechanics of active pursuit of a broad diversity of aquatic predators.

P2-79 SOUTH, KE*; LEININGER, EC; New College of Florida; *kelly.south15@ncf.edu*
The role of laryngeal physiology in generating advertisement calls of Xenopus muelleri
Understanding the mechanisms underlying the evolution of behaviors relies on identifying modifications to neural and muscular circuit physiology. Male African clawed frogs (*Xenopus*) produce species specific advertisement calls that vary in temporal complexity. Species that produce temporally simplified advertisement calls (*X. borealis* and *X. boumbaensis*) utilize different laryngeal mechanisms for generating these calls. Unlike *X. boumbaensis*, *X. borealis* faithfully converts neural stimulation into muscle contractions that mirror call temporal patterns. To understand whether this mechanism is conserved, we examined *X. muelleri*, a species closely related to *X. borealis*, that produces advertisement calls of intermediate complexity. We identified stimulation parameters required to produce muscle contractions approximating the burst advertisement call of *X. muelleri*. After recording vocalizations from live frogs, we stimulated laryngeal nerve rootlets of the isolated larynx with stimulus bursts over a range of inter-stimulus intervals while recording electromyograms and tension from the laryngeal muscle. Stimulus bursts delivered to the larynx with inter-stimulus intervals (50 - 60 ms) longer than the average inter-pulse interval recorded from intact frogs (45 ms) produced the two discrete EMG and tension transients necessary for a burst call. However, stimulus bursts delivered to the isolated larynx with shorter inter-pulse intervals (20 - 40 ms) resulted in maintained tension, which would correlate to producing a single sound pulse rather than a burst. These results confirm that *X. muelleri* displays faithful conversion of neural stimulation to muscle contractions, but can only do so at intervals at or longer than those of *in vivo* calls.

107-1 SPAIN, D.*; CHAVEZ, B. ; MENDOZA, V. ; Dominican University of California; *diara.spain@dominican.edu*
An Ocean Acidification Case Study: Non-Science Majors vs Science Majors
A case study was used to introduce ocean acidification to undergraduates enrolled in an environmental course for non-science majors and an introductory research course for science majors. The instructor facilitated class discussions on ocean chemistry and carbon dioxide emission data was provided to review and analyze. The next month, students were given a survey asking questions about the case study content. The preliminary survey results for both student populations were encouraging in that most of the multiple choice content questions were answered correctly. For example, all students recalled that increased carbon dioxide emissions were shown in the Keeling Curve. However, when asked to write short answers the science majors wrote more detailed and accurate descriptions. While these datasets include two student populations, this ongoing project will include four courses investigating the use of case studies in undergraduate science courses.

71-4 SPEISER, DI*; CHAPPELL, DR; KINGSTON, ACN; Univ. of South Carolina; *speiser@mailbox.sc.edu*

The Eyespots of Chiton (Mollusca: Polyplacophora) are Associated with Spatial Vision

Research on visual systems has focused primarily on the paired cephalic eyes found in many taxa, but these are not the only eyes in the natural world. It is likely that we have much to learn from distributed visual systems that include dozens or hundreds of separate light-detecting structures. To better understand relationships between the structure and function of distributed visual systems, we are comparing how morphological differences between light-sensing structures in chitons relate to the visually-guided behaviors of these animals. Sensory organs - termed aesthetes - are embedded within the shell plates of all chitons. In some species, the aesthetes are interspersed with small eyes. In other species, each aesthete is associated with an eyespot. Previously, we established that the eyes of chitons are associated with spatial vision. Here, we find that chitons with eyespots also engage in behaviors consistent with spatial vision. For example, we find that *Chiton tuberculatus* orients to static objects with angular sizes as small as 10°. We also note morphological differences between species of *Chiton* that may be relevant to vision: the eyespots in some species (e.g. *C. tuberculatus*) lie underneath shell material that is transparent and convex, whereas eyespots in other species (e.g. *C. marmoratus*) are associated with overlying shell material that is transparent, but flat. We also find that the eyespots of *Chiton* are separated by narrow angles (0.5°) similar to those observed between the ommatidia of high-acuity apposition compound eyes. Lastly, we explore the degree to which chitons may gather spatial information by comparing input between photoreceptors within neighboring light-detecting structures rather than comparing input between photoreceptors within the same structures.

74-6 SPENCE, AR*; TINGLEY, MW; University of Connecticut; *austin.spence@uconn.edu*

Response to novel thermal and hypoxic challenges from populations across a hummingbird's elevational range

Species ranges are shifting to track thermal or precipitation regimes in response to global climate change. For species with large distributions that contain a broad range of abiotic conditions, responses to novel abiotic conditions of newly colonized areas may be dependent on the adaptation and acclimatization to the environment of the source population's location. Differential population responses have been shown to reduce performance on the leading edge of ranges of invertebrates by reducing the effectiveness of local adaptations, although similar research in endothermic vertebrates is lacking. Montane habitats provide a natural experimental framework because species with wide elevational ranges experience systematic changes in temperature and oxygen. In this experiment, we collected Anna's Hummingbirds (*Calypte anna*) from three different elevations across their elevational range: 0 meters above sea level (asl), 1000 meters asl, and 2500 meters asl. We performed two metabolic tests to examine aerobic performance and thermal tolerance, hovering metabolic rate and torpor use and efficiency, respectively. We performed these tests at the middle of the species elevational range to understand metabolic efficiency inside of the range. We subsequently performed these tests again at 3500 meters asl, 1000 meters above their elevational range limit, to test how the source populations respond to novel temperature and oxygen regimes. We collected dry mass of heart, lungs, liver, and intestinal tract to account for aerobic performance. This study will provide information on whether populations along the elevational gradient will react differently to elevational range shifts associated with global climate change, providing a step forward to mechanistically testing limits of a species ability to respond to global climate change.

53-2 SPENCER, TS*; HU, DL; Georgia Institute of Technology; *tspencer6@gatech.edu*

Sniffing Scaling Study for Superior Sensing

Mammals such as dogs are known for their keen sense of smell and have been relied upon for their ability to find odor sources. A key component to the mammalian sense of smell is the dynamic sniff cycle. We find the rate at which mammals sniff scales at approximately the same rate as their maximum possible sniff frequency. We rationalize this trend due to the limits of their respiratory anatomy and physiology. Lungs of all mammals are constrained to approximately the same pressure whereas the geometry of the system increases with body size. This scaling argument and other literature suggests that mammals sniff as quickly as possible. Conversely, we find through oscillatory wind tunnel experiments and computational simulations that lower sniffing frequencies provide better odor collection in straight, rectangular channels. We proceed from rectangular channels to investigating the effect of biological nasal cavity shapes helping to mitigate odor collection. We apply insights gleaned from our biological and experimental results to design an electronic nose pre-concentrator for improved chemical sensing.

49-3 SPENCER, R-J; Western Sydney University; *r.spencer@westernsydney.edu.au*

Global Extinction of Freshwater Turtles.

The clock is ticking for many of the world's freshwater turtles. Throughout Asia, many species are now on the brink of extinction because of over-harvesting for food and the pet trade and in Australia, some the most common and widespread species have declined by up to 91% as a result of human related mortality (eg. cars) and habitat-quality related diseases. Invasive species are also a major factor in population declines and hamper attempts to recover populations. Turtles are of major importance in river ecosystems and decline or loss of abundant consumers, such as turtles, will have serious effects on the ecosystem, potentially impacting water quality, biological diversity, general river health and the services these ecosystems currently provide. Here I propose pioneering "macro-conservation" programs to halt the decline of freshwater turtles. These programs are citizen science and community driven but are based on fundamental ecological principles that define turtle life histories. I will demonstrate how programs like "Turtles in Schools" programs and religion and cultural traditions can be at the forefront of conservation and species recovery.

137-1 SPILLANE, JL*; LESSER, MM; MACMANES, MD; PLACHETZKI, DC; University of New Hampshire; *jlh1023@wildcats.unh.edu*

Sponges: Degenerate Form or Ancestral State?

The ability of organisms to co-opt genes for new purposes, or to neofunctionalize gene duplicates, is a major focus of evolutionary biology and comparative genomics. However, relatively less attention has been paid to the role of gene loss as a driver of adaptive shifts in organismal biology. Loss of function evolution has been shown repeatedly in microbial species living in close relationships with host taxa, and in the host taxa themselves. Poriferans, with their diverse microbiome communities, are excellent candidates for horizontal gene transfer and gene loss that could result in degeneracy of morphological traits and loss of gene families. Here we develop a catalogue of reference-based gene presence/absence from estimates of orthology across a selection of metazoan genome-scale datasets. We then apply a stochastic model for binary trait evolution conditioned on gene presence/absence data across lineages and gene categories. Using this model, we find evidence of widespread gene loss in sponges compared to other lineages, and our findings are consistent with the hypothesis that extant sponges represent a degeneration of ancestral complexity.

P1-260 SPOONER, HC*; HERNANDEZ, GV; BURRIN, D; MAJ, MA; MANJARIN, R; BLANK, JM; California State University, San Luis Obispo, Baylor College of Medicine, Houston; *hspooner@calpoly.edu*

Intramuscular Lipid Accumulation in a Pig Model of NAFLD

This study is part of a project to develop a model for pediatric non-alcoholic fatty liver disease (NAFLD) using leptin resistant neonate pigs. NAFLD is characterized by a build up of lipids in the liver related to insulin insensitivity. In the skeletal muscles of humans, rats, and pigs, insulin insensitivity is known to be accompanied by an increase in intramuscular fat, both between muscle cells and inside the cells. Since skeletal muscle normally uses the greatest proportion of the body's dietary lipids, this build up indicates that lipids are being stored instead of oxidized, leading to further build up in other places. The purpose of this experiment was to quantify the lipid accumulation in muscle of high-fat fed pigs compared to control animals and to assess changes in muscle fiber composition in response to the diet. 10 day old piglets were allocated to either control or high-fructose high-fat diet for 10 consecutive weeks. On week 10 animals were euthanized and longissimus dorsi, gastrocnemius and soleus were collected for histology and immunohistochemistry analysis. Tissue sections were stained for lipid with the oil red O stain. Lipid deposition was analyzed based on stain intensity, number of cells stained, and extracellular lipid deposit areas. The results are discussed in the larger context of previous research and the overall project. Funding from ARI#58873, STRIDE#35466

121-4 SPRANGER, RS*; SINERVO, B; Univ. of California, Santa Cruz; *rsprange@ucsc.edu*

Thermal Acclimation Potential of Ambystoma and Dicamptodon Salamanders

An ectotherm's ability to acclimate to changes in environmental temperature may provide a buffer from extinction. Acclimation capacity reflects the ability of an individual to alter its critical thermal limits and performance as a function of temperature. Here, we assessed the acclimation capacity for members of the genus *Ambystoma*, and a cool-adapted relative, *Dicamptodon*. Because members of these genera may have evolved a capacity to acclimate due to their variation in life history strategies, we hypothesized that obligate paedomorphic species will have little capacity for acclimation, while metamorphic and facultative paedomorphic species will have the highest acclimation capacity. We raised larvae of *Ambystoma mexicanum*, *Dicamptodon ensatus, Ambystoma mavortium*, and *Ambystoma macrodactylum* in our lab under treatments of 15, 18, and 21 °C, which reflect predicted climate change scenarios, and allowed them to acclimate for 4-6 weeks. After a 3-hour cooling period, we measured the thermal preference of each individual in aquatic gradients for two hours. The larvae were then transferred to a second temperature in a block design (15, 18, 21 °C) for 4 weeks of acclimation and we again measured thermal preference. Our results indicate that *A. mexicanum*, an obligate paedomorph, is unable to adjust its thermal preference with rising temperatures and show little capacity for acclimation ($p<.047$). Facultative paedomorphs, like *A. mavortium* and *D. ensatus*, and metamorphic *A. macrodactylum* show increasing thermal preference with temperature and show a greater capacity for acclimation. The greater acclimation capacity suggests that these species will not just survive the elevated temperatures expected under climate warming, but maintain normal function, while *A. mexicanum* will not be able to adjust as successfully.

106-3 SRYGLEY, RB; USDA-Agricultural Research Service; *robert.srygley@ars.usda.gov*

Parental Photoperiod Prolongs Egg Diapause in a Montane Population of Mormon crickets

To persist in variable climates, many organisms adopt switching between phenotypic states as a way of hedging their bets. Variable release from egg dormancy is a form of bet hedging that has major effects on population dynamics. Conventionally, Mormon crickets are thought to require a single winter to hatch, but at high elevation (2400 m) in the Bighorn Mountains, Wyoming, the population was shown to be biennial with development in the first summer arrested in a early embryonic stage known as ‘egg diapause.' However, when males and females from the Bighorn Mountains were collected in August and paired in the lab, all but one of 43 females laid some eggs that reached late embryonic stages called ‘embryonic diapause' and hatched after a single winter. Critical daylength is typically shorter as altitude or latitude increases. Reaching embryonic diapause prior to loss of growing degree days for development is essential for hatching the following spring. Without sufficient time to reach embryonic diapause, egg diapause is an alternative overwintering strategy for montane Mormon crickets. I tested the hypothesis that a critical parental daylength exists in the Bighorn Mountain population of Mormon crickets for which the eggs that are laid remain in egg diapause and delay development until the following summer. To test whether photoperiod serves as the parental cue, mating pairs were set in the same daily temperature and humidity profiles with twenty pairs on short daylength (12:12) and twenty pairs on long daylength (15:9). Females in short daylength laid more eggs that delayed development. They were also more likely to lay inviable eggs. Other fitness measures, such as hatchling mass, nymphal survivorship, and adult mass were not different between parental treatments. Diapause termination distributed over multiple years probably constitutes a bet-hedging strategy in an unpredictable environment.

141-2 ST. JOHN, ME*; MARTIN, CH; Univ. of North Carolina, Chapel Hill; *Michelle.e.stjohn@gmail.com*

The cascading effects of aggression on trophic innovation and reproductive isolation within an adaptive radiation of pupfishes

Behavioral changes in a new environment are often assumed to precede the origins of evolutionary novelties. Here, we examined whether an increase in aggression is associated with a novel scale-eating trophic niche within a recent radiation of *Cyprinodon* pupfishes endemic to San Salvador Island, Bahamas. We measured aggression using multiple behavioral assays and used transcriptomic analyses to identify candidate gene pathways underlying aggression across three sympatric species in the San Salvador radiation (generalist, snail-eating specialist, and scale-eating specialist) and two generalist outgroups. Surprisingly, we found increased behavioral aggression and differential expression of aggression-related pathways in both the scale-eating and snail-eating specialists. Our results indicate that aggression is not unique to scale-eating specialists. Instead, selection may increase aggression in other contexts such as niche specialization in general or mate competition. Alternatively, increased aggression may result from indirect selection on jaw size, pigmentation, or metabolism—all traits which are highly divergent in this system, exhibit signs of selective sweeps, and may have pleiotropic effects on aggression. Additionally, we discuss whether androgen levels vary across pupfish species, and how varying levels of aggression affect mate preference and feeding behavior.

P1-8 STAAB, KL*; MARTINSON, HM; SCULLION, J; McDaniel College; *kstaab@mcdaniel.edu*

A framework to incorporate collaborative research on habitat health in the undergraduate classroom

We piloted a course-based undergraduate research program assessing ecosystem health in a restored stream. Freshwater ecosystems are sensitive to anthropogenic changes and while restoration efforts are noble, measurements of ecosystem function are often superficial rather than integrated. With funding from HeidelbergCement through the Quarry Life initiative, we infused authentic research projects into three upper-level courses: Conservation Biology, Ecology, and Animal Physiology. Our model is flexible to serve as a template for partnerships between industry and small undergraduate institutions to assess effectiveness of habitat restoration. Each course used complementary methods to examine presence, abundance, physiological condition, and activities of animals at restored sites to identify functional indicators of habitat health, contributing to an integrative robust assessment. Students in Conservation Biology deployed camera traps to assess presence, diversity, and behaviors of terrestrial mammals in the ecosystem, while students in Ecology examined plant communities and invertebrate abundance and diversity. Students in Animal Physiology assessed health metrics of fish living in the stream. Each student group developed their own hypotheses, research design, and data analysis under this framework resulting in high-impact outdoor learning. Because small schools are often resource-poor or lack field sites, we see mutualistic benefits in collaboration with green-minded industry partners. We propose that professors anywhere, in differing areas of expertise (e.g., chemistry, microbiology, geology) can integrate research into classes by incorporating small changes that not only increase productivity for industry partners, but also broaden participation in undergraduate research.

S10-7 STAGER, M*; CHEVIRON, Z; University of Montana; *maria.stager@umontana.edu*

An analytical framework for dissecting complex traits: a case study of avian physiological flexibility to cold acclimation

Individuals maintain a dynamic regulatory system that may confer the flexibility to reversibly match their phenotype(s) to fluctuating environmental conditions. This process often involves dramatic modification across multiple subordinate traits. However, the relative influence of these component traits on whole-organism performance is poorly understood in natural systems. As a case study, we explore the contribution of subordinate phenotypes to a complex, multi-level trait related to cold tolerance in a wild avian system by combining assays of gene expression, tissue-level- and whole-animal physiology in a novel network analytic framework. Our work indicates that organismal performance is disproportionally influenced by few subordinate traits. We use these findings to guide suggestions for a purpose-driven approach to studying the mechanistic basis of dynamic phenotypes more generally. We discuss the pros and cons of alternative analytical techniques for use with these multifaceted datasets and the interpretation of the results. Our results shed light on the mechanisms underlying seasonal phenotypic flexibility, and provide a general analytical framework for other evolutionary studies of similarly complex physiological traits.

31-6 STANDEN, EM*; TURKO, AJ; University of Ottawa, Canada, University of Guelph, Canada; *estanden@uottawa.ca*

The art of unsticking: Biomechanics of terrestrial adhesion in the amphibious fish Kryptolebias marmoratus

The mangrove rivulus *Kryptolebias marmoratus* is a small amphibious fish that inhabits tropical mangrove swamps. During the dry season, these aquatic habitats can disappear, forcing fish to seek water elsewhere or burrow into logs and debris until water returns. Water conditions in these habitats can also become acutely unfavourable (e.g. hypoxia, elevated H2S, too hot), and mangrove rivulus respond by escaping onto land. Conspecific aggression can also cause fish to leave water and travel over land to unoccupied pools. Mangrove rivulus have developed a dynamic locomotory repertoire and they readily move between water and land with a large amount of control. Rivulus emerse from water in an explosive behaviour and readily stick above the water line to mud, wood and leafy substrates (in the wild), or glass and plastic (in the lab). The fish can easily adhere to vertical and even inverted horizontal surfaces and surface roughness and humidity do not appear to hinder their performance. More impressively mangrove rivulus perform controlled 'unsticking' maneuvers and can gain height by jumping from vertical surface to vertical surface in a seemingly organized and directional manner. This study uses high-speed video and force measurements in combination with fine anatomical description of the fins, scales, and trunk musculature to determine the mechanisms used to control adhesion-based maneuvering in these tiny fish. Body orientation and surface area contact are highly variable during unsticking events suggesting that another smaller scale mechanism is acting to provide precise control for surface adhesion. Preliminary data points to skin surface structure as a possible mechanism to control release timing during unsticking events in this tiny amphibious fish.

60-5 STANTON, DS*; HARPER, SJ; BRLANSKY, RH; Univ. of Florida IFAS-CREC, Lake Alfred, Washington State Univ., Prosser; *stantond2@ufl.edu*

Using RNAscope As A Diagnostic Tool To Identify Two Citrus Viroids in Plant Tissues

Viroids are small circular single-stranded RNA virus-like organisms that cause disease on economically important crops such as potato, tomato, hops and citrus, reducing plant growth, vigor, and yield. Viroid infections in plants are largely diagnosed by RT-PCR, by dot blot hybridization, or PAGE-gels. Citrus exocortis viroid (CEVd) was one of the first viroids characterized and the causal agent was shown to be a short 371 nucleotide single-stranded RNA molecule. Citrus cachexia viroid (CVd II) is a similar viroid discovered 10 years later that has been shown to be 300 nucleotides long and is the causal agent of some cases of xyloporosis. Due to their small size locating these RNAs in plant tissue has been problematic. Traditional plant *in situ* hybridization studies are often limited by specificity of binding, limited target signal amplification. Additionally, traditional *in situ* hybridization methods are limited to a single specific probe designed from a known viroid sequence. RNAscope (Advanced Cell Diagnostics Inc., Newark, CA), however is a novel *in situ* hybridization method that has been developed to hybridize double Z probes along an RNA sequence up to 1kb long to which a scaffold is built to allow for greater amplification of signal for each Z probe. The scaffold contains multiple binding sites for the detection enzyme when bind to a colorimetric or fluorometric substrate. Here we present data showing that RNAscope can be used to detect CEVd and CVd-II in citrus petioles, stem, and root tissues. Additionally, a RNAscope duplex assay can be used to detect co-infection of viroids. RNAscope has broad application in plant research including the detection of plant RNAs and RNAs of Plant pathogens.

S12-2 STARK, Alyssa Y.; Villanova University; *alyssa.stark@villanova.edu*

Stick or Slip: Adhesive Performance of Geckos and Gecko-inspired Synthetics in Wet Environments

The gecko adhesive system has inspired hundreds of synthetic mimics principally focused on replicating the strong, yet reversible properties of the natural system. Indeed, geckos can attach and detach with relative ease while scaling vertical and even inverted surfaces. Perhaps even more remarkable, they can do this amidst spatially and temporally dynamic environmental conditions, including variation in substrate surface quality, temperature, and humidity. For geckos native to the tropics, substrates they utilize wet from high humidity and frequent rain. Paradoxically, van der Waals forces, the principal mechanism for gecko adhesion, reduce to zero when substrates separate even slightly by entrapped water layers. A series of laboratory studies show that geckos maintain their adhesive performance in many wet conditions, despite the negative repercussions of water in their environment. The mechanism for this is not fully clarified, and likely ranges in scale from the chemical and material properties of the gecko's contact structures (setae), to their locomotor biomechanics and decision making behavior when encountering water on a substrate they move across. Current work has focused on applying our results from the natural system to synthetic gecko-inspired adhesive systems, and improving their performance in wet conditions. Gecko-inspired synthetic adhesives have also provided a unique opportunity to test standing hypotheses about the natural system in non-pristine, semi-natural conditions replicated in the laboratory.

S8-2 STAYTON, C. Tristan; Bucknell University; *tstayton@bucknell.edu*

Moving beyond the peaks: combining multivariate performance surfaces in studies of ecomorphological diversification

Adaptive landscapes have inspired evolutionary research for nearly a century. Until recently such landscapes have mostly served as metaphors rather than quantitative frameworks for research. Current methods which utilize landscape frameworks for research primarily employ evolutionary modelling, usually fitting data to Ornstein-Uhlenbeck models to make inferences about adaptive peaks. Recently alternative methods have been developed which utilize combinations of performance surfaces - multivariate visualizations of relationships between phenotype and functional performance - to explore features of adaptive landscapes and explain the distribution of species in phenotypic space. I illustrate these new methods using data on turtle shell shape and information on performance for three shell functions - strength, hydrodynamic efficiency, and self-righting ability. The performance surfaces for these functions are given varying weights and then combined to obtain a set of predicted performance optima in shell shape space. The distribution of actual turtle shells in shape space significantly overlaps these optima, particularly when the distribution of both optimal and "near optimal" (performance values within 99% of the maximum) locations are considered. The performance surface methods outperform modelling-based approaches in locating reasonable adaptive peaks and explaining the shape of the phenotypic distributions of turtle shells. In addition, these methods provide information about the relative importance of the individual functions in guiding turtle shell evolution and potentially in determining fitness. Performance surface-based methods show great promise for allowing researchers to more directly connect functional performance with macroevolutionary patterns of diversification, and to explain the distribution of species across phenotypic space.

123-3 STEELE, AN*; MOORE, PA; Bowling Green St. Univ.; Univ. of Michigan Biological Station; *ansteel@bgsu.edu*

Defining Exposure: Contribution of Exposure Paradigm Characteristics to Impairment of Aquatic Organisms

Aquatic ecotoxicology has undergone vast growth in the understanding and modeling of the spatially and temporally dynamic nature of toxicants in fluvial aquatic systems (Corwin et al. 1997; Schindler et al. 1995). However, in classic laboratory toxicity tests used to define regulatory standards, organisms are subject to static exposures that use a set of highly controlled exposure conditions (Asifa et al. 2016; Santos Miron et al. 2004). Thus, contaminant effects resulting from static toxicity testing are disparate from the results of exposure conditions experienced by organisms in natural systems (Neal and Moore 2017; Harrigan and Moore 2017). The purpose of this study is to understand the effects of the structural characteristics (concentration, duration, and frequency) of temporally and spatially variant toxicant plumes on aquatic organisms to construct a realistic definition of exposure to apply to environmental assessment. Current research has not evaluated the effects caused by all exposure paradigm characteristics nor determined which characteristic or combination of characteristics causes the most detriment to organisms. This study used escape response of *F. virilis* crayfish from the predatory odor of *M. salmoides* following exposure to the herbicide, atrazine. Atrazine was delivered in pulses to flow through exposure arenas for a total of 47 hours while manipulating the concentration, frequency, and duration of the herbicide pulses. Escape response of crayfish was analyzed and resulted in treatment dependent reduction in olfactory response to predatory odor. These findings aid to elucidate the relative contribution of these characteristics of exposure to negative effects on organisms.

P1-112 STEELE, A*; LANGRO, J; HUNTER, T; LYNCH, KS; Hofstra University; *asteele1@pride.hofstra.edu*

The role of prolactin in female brown-headed cowbird responses to nestling begging stimulus

Nearly 1% of all bird species are obligate brood parasites. Obligate brood parasites do not build their own nests, incubate their own eggs or provision their own young. Recent results from our lab reveal that a critical maternal care-related brain region exhibits prolactin transcriptome insensitivity. Here, we further examine the effects of prolactin on brain and behavior of brood parasites. Adult female brown-headed cowbirds (Molothrus ater), a brood parasite ubiquitous across North America, were treated with either estrogen, estrogen + prolactin or saline as a control. We measured behavioral response of females in these treatment groups in a dichotomous choice test in which random tones and nestling begging sounds were broadcast. Immediately following behavioral measures, female subjects were placed in soundproof auditory chambers and exposed to random tones or nestling begging sounds to examine neural responses to these auditory stimuli among the treatment groups. Behavioral result revealed no significant difference across treatment groups in time spent near nest, time spent on nestling begging side or time spent on nest/control cup. In addition, no significant difference was observed within each treatment group in the time females performed these behaviors simulated nestling/nest side of the chamber as compared to the random tone/control cup side of the chamber. Examination of neural responses to random tones or nestling begging in treated and non-hormone treated females will determine whether a combination of auditory stimuli and hormone treatments also exhibits prolactin insensitivity. We are repeating these same tests in a closely related non-parasitic species (i.e. red-winged blackbird; Agelaius phoeniceus) to determine if these same measures do exhibit prolactin sensitivity in a maternal species.

109-4 STEIN, LR*; SINNER, M; IFFERT, RQ; HOKE, K; Colorado State University; *lrstein@colostate.edu*

Sex on the brain: Effects of reproduction on brain and behavior in Trinidadian guppies

The experience of reproducing is one of the most important life history events for many organisms. Yet although there is a rich literature documenting the physiological and behavioral changes that organisms undergo during reproductive events and how this affects future reproduction, our understanding of how these changes influence behavior in other contexts is limited. Here, we investigate the effects of reproduction on aggression, exploration, and anti-predator behaviors across three populations of male Trinidadian guppies (*Poecilia reticulata*). We additionally examined changes in neural activation in response to a model predator across experienced and virgin males. 24 hours after reproduction, males were less active, more cautious, and less aggressive than their virgin brothers, and showed greater neural activation in areas of the brain associated with fear. However, many of these behaviors returned to pre-reproduction levels after three or seven days. Our results suggest that reproduction alters behavior and neural activation over short timescales in Trinidadian guppies, providing insights into adult behavioral plasticity and how these changes may influence life histories and reproductive success.

57-4 STEINWORTH, BM*; JEAN, GH; RYAN, JF; MARTINDALE, MQ; Univ. of Florida Whitney Laboratory for Marine Bioscience, University of Miami; *bsteinworth@ufl.edu*

Are Hox genes involved in asexual reproduction in the upside-down jellyfish Cassiopea?

Hox genes have long been known to control embryonic formation of the anterior-posterior axis in bilaterians, and more recent work has shown them to be necessary for the formation of the oral-aboral axis during cnidarian embryogenesis. Here we investigate the role of Hox genes during asexual reproduction using the upside-down jellyfish, *Cassiopea*. *Cassiopea* is a scyphozoan that reproduces sexually at the medusa stage and asexually at the polyp stage. The clones produced asexually behave like larvae: both use cilia to swim with the future aboral pole facing forward. What genetic signals control the formation of these larva-like clones? Are Hox genes re-deployed in somatic tissue, or is this new individual's body axis patterned by a different mechanism? To answer these questions, we present phylogenetic analyses of Hox genes from Hydrozoa, Scyphozoa, Staurozoa, and Cubozoa, as well as both both Hexacorallia and Octocorallia within Anthozoa. For the Cassiopea genes identified in this phylogeny, we characterize spatial and temporal expression by *in situ* hybridization. During embryogenesis, *Cassiopea* Hox genes are expressed in spatially restricted domains along the oral-aboral axis, consistent with a role in axial patterning and similar to patterns present in other cnidarians. Some Hox genes are also expressed during asexual reproduction in similar patterns, suggesting these genes serve a role after embryonic development to pattern the asexually produced individual. Characterizing the cnidarian Hox genes and understanding the full extent of their roles will provide insight into the Hox complement of the cnidarian-bilaterian ancestor and the origin of both cnidarian and bilaterian body forms.

60-3 STEVEN, JC*; COLLAR, DC; BRODIE III, ED; DELPH, LF; Christopher Newport University, University of Virginia and Mountain Lake Biological Station, Indiana University; *janet.steven@cnu.edu*

The relationship between genetic and functional architecture in leaf, physiological, and flower traits in Silene latifolia

Plants with indeterminate inflorescences require sustained rates of photosynthesis to support continued flower production and thus increased fitness. In dioecious species, flower size and number tradeoffs may also favor a greater number of smaller flowers in males to increase overall pollen production, but genes expressed during development affect both leaves and floral organs, resulting in a potential conflict between photosynthetic rate and flower number. We investigated the quantitative genetic and functional architecture among leaf, physiological, and flower traits in *Silene latifolia* in an effort to determine whether functional tradeoffs reflect constraint in underlying genetic correlations, and whether the net functional relationship between performance variables is similar to the tradeoff between performance traits. We grew 595 plants of known pedigree in a greenhouse and measured flower size and number, leaf size and thickness, photosynthetic rate, and transpiration. We found a weak negative functional correlation between photosynthetic rate and flower number in both sexes, and a stronger negative genetic correlation between these performance traits in males but not females. Thicker leaves resulted in increased photosynthetic rate but reduced flower number in performance gradients in males, and the underlying genetic correlations for these traits mirrored this pattern. However, the net functional relationship between performance variables was close to 0. Integration among the measured traits may mitigate the constraints of this functional tradeoff.

P3-46 STEVENSON, JPJ; CHENEY, JA*; DURSTON, NE; USHERWOOD, JR; WINDSOR, SP; BOMPHREY, RJ; Univ. of Bristol, UK, Royal Vet. College, Hatfield, UK; *jcheney@rvc.ac.uk*

Pose and shape changes of avian flight surfaces for control

Birds control their flight by changing the orientation (pose) and shape of their wings and tail. There is a large combination of parameters that can be altered, and the way in which these are coordinated to achieve specific flight trajectories is not well understood. To gain insight into these control strategies, we reconstructed time-resolved point-cloud sequences of falconry birds making fine changes to their flight surfaces as they glided down a straight corridor. The point clouds were derived from disparity maps between high-speed cameras positioned above and below the flight test region. We report on changes to the pose and shape of the birds, and assess whether coordinated wing-tail movements exhibit consistency and covariance.

P1-28 STEWART, MS*; KRUPPERT, S; SCHMITZ, L; SUMMERS, A; Scripps College, Univ. of Washington, Claremont McKenna College; *morganstewart012@gmail.com*

Written in Bone: Damage Patterns in Agonopsis vulsa Armor Plates

Armor, in the sense of heavy plates or scutes, has evolved many times in fishes suggesting a common selective pressure or many different selective pressures. In the engineering world armor can defend against impact, abrasion, cutting, and/or crushing. In the realm of biology we must add display, offensive battery, and ritualized combat to the functions of armor. Here we explore the notion that looking at the damage pattern on armor over ontogeny can reveal something of function. For example, armor that is unscathed from birth to death likely serves only as display, else it would bear the marks of use. We used the Northern Spearnose Poacher (*Agonopsis vulsa*), a heavily armored benthic fish, belonging to the family Agonidae. *A. vulsa's* bony scales preserve damage incurred during the fish's life. Using CT scans and digital 3D modeling, a categorical systemization of damage was created, assigning values to specific degrees of macroscopic damage. These degrees of damage were investigated before data collection through observation of many scales, both damaged and undamaged. To ground truth damage modes scales were intentionally damaged (shattered, abraded, snapped, and crushed) and observed using SEM. Categories of damage were designated as caused by impact (mild or severe breakage) or caused by abrasion (mild or severe wear). This systemization was applied to 34 *A. vulsa* specimens ranging in trunk length from 2.3 cm to 14.2 cm. Large fish (over 9 cm) and small fish (under 9 cm) showed different patterns of impact damage locations along the fish. Large fish also showed significantly more abrasion damage. These patterns of damage may provide new insights into the life history of this small, largely unstudied fish.

137-3 STEWART, JR*; MENDEZ DE LA CRUZ, FR; East Tennessee State Univ., Universidad Nacional Autonoma de Mexico; *stewarjr@etsu.edu*

Novel Placental Structure in the Mexican Lizard, Mesaspis viridiflava.

Yolk sac placentation is a distinctive characteristic of the evolution of squamate viviparity yet knowledge of the patterns of variation is limited because placental development has been described in relatively few lineages. Gerrhonotine lizards (Family Anguidae) are of interest in exploring placental evolution because viviparity is the predominant reproductive mode within this lineage. We studied placental ontogeny using light microscopy for an embryological series of the Mexican gerrhonotine lizard, *Mesaspis viridiflava*. The placental interface of this species is dominated by yolk sac placentation. The unusual placental structure is a specialization for maternal-fetal exchange incorporating elements of the yolk cleft/isolated yolk mass complex, a shared, derived trait for squamate reptiles. Although this extraembryonic membrane system is a prominent feature of placental evolution among squamates, the unique attributes of placentation in *M. viridiflava* are supported by a novel pattern of yolk sac vascular development. A prominent feature of the placenta is a zone of uterine and embryonic epithelial cell hyperplasia located at the upper shoulder of the yolk mass, often extending above the yolk mass. Phylogenetic variation in the yolk sac placenta is likely to reflect variation expressed in oviparous antecedents as well as specializations for maternal - fetal exchange arising subsequent to the evolution of viviparity. The yolk sac placenta of *M. viridiflava* exemplifies both characteristics. Placental specializations of this species are consistent with a pattern of matrotrophic embryonic nutrition and have evolved in a unique lineage specific developmental pattern.

P3-17 STEWART, TA*; AIELLO, BR; GAU, GF; BHAMLA , S; SHUBIN, NH; University of Chicago, Georgia Institute of Technology; *tomstewart@uchicago.edu*

The convergent evolution of blinking in mudskippers and tetrapods

Approximately 360 million years ago, tetrapods colonized the terrestrial environment. This water-to-land transition is marked by a suite of behavioral and morphological adaptations. Among these, was the origin of blinking - the periodic occlusion of the eye by one or more membranes. Blinking behaviors coat the cornea in a liquid film, which is critical for epithelial cell health, lubrication, and cleaning the eye of debris. Mudskippers (Oxudercidae) are a second lineage of fishes that have evolved to spend the majority of their day on land. Here we describe how mudskippers have evolved the ability to blink, convergent with tetrapods, by studying the Indian mudskipper *Periophthalmus septemradiatus*. High speed kinematics show that the eye is retracted ventrally and this displaces the dermal cup (an epithelial fold analogous to the lower eyelid of tetrapods), which moves dorsally to cover the cornea. Rates of blinking are associated with ambient humidity, indicating the behavior functions for eye-wetting. To characterize how this anatomy has evolved, we compare *P. septembradiatus* with the closely related fully-aquatic round goby, *Neogobius melanostomus*; specimens were soft-tissue contrast stained by phosphomolybdic acid and CT-scanned. We also describe histology of the eyes and the dermal cup, which reveals that, unlike extant tetrapods, mudskippers lack associated 'tear' glands. Collectively, these behavioral and anatomical data show how complex behavior, such as blinking, can occur in systems that are unexpectedly simple (i.e., without new associated musculature or glands), and this informs the range of strategies that could have been deployed during initial stages of the water-to-land transition of tetrapods.

70-5 STEWART, TA*; LEMBERG, JB; SHUBIN, NH; University of Chicago; *tomstewart@uchicago.edu*

The dorsoventral patterning and asymmetry of paired fins

Limbs are asymmetrical in the dorsoventral axis—skeleton, musculature, epithelial appendages, innervation, and sensory endings all exhibit this polarity. It is less clear whether pectoral and pelvic fins, which are homologous to limbs, exhibit similar asymmetries and, if so, when they might have evolved. Here we present a comparative study of anatomy and developmental genetics and argue that dorsoventral asymmetries are plesiomorphic among the paired fins of gnathostomes. Micro-CT data from the pectoral and pelvic fins of several species, including *Danio rerio* (Actinopterygii), the little skate *Leucoraja erinacea* (Chondrichthyes) and *Tiktaalik roseae* (Sarcopterygii), show that asymmetries are common among both the dermal and endoskeletal systems of paired fins. We also test whether the developmental and genetic mechanisms that establish dorsoventral asymmetry in limbs are shared with paired fins. Using laser microdissection and RNA sequencing, we compare gene expression in the dorsal and ventral portions of developing paired fins in *L. erinacea*. Comparing these results to what is known of mouse and chick development, we discuss how the breaking of dorsoventral symmetry might have occurred in the earliest paired fins.

S2-12 STEWART MERRILL, TE*; HALL, SR; RAPTI, Z; CáCERES, CE; Univ. of Illinois at Urbana-Champaign, Indiana University; *tarastew@illinois.edu*

Variable Immunity and its Consequences for Disease

Epidemiological theory often treats host susceptibility as a fixed constant. Is this assumption accurate and how do deviations from it affect our understanding of infectious disease? I explore the causes and consequences of variable susceptibility in a one-host one-parasite system: the zooplanktonic host, *Daphnia dentifera*, and its fungal parasite, *Metschnikowia bicuspidata*. From June to December 2017, I tracked *Metschnikowia* epidemics in six naturally occurring *Daphnia* populations and measured host susceptibility and its underlying immunological traits to identify its relative role in driving epidemic emergence. I found that epidemics could not be predicted from *Metschnikowia* exposure alone but depended critically on the interaction between parasite exposure and host susceptibility. *Daphnia* hosts were exposed to low levels of *Metschnikowia* for months preceding epidemics, and epidemics only emerged when *Daphnia* immune defenses declined to a critical minimum. Host susceptibility showed strong variation across scales, from the individual-level to the within- and among-population levels, and I discuss the extent to which ecological factors may be driving this variation.

P1-110 STIERHOFF, ES*; CARPENETTI, JM; BUTLER, MW; Lafayette College, Easton, PA; *stierhoe@lafayette.edu*

The Relationship Between Degree of Immune Challenge in House Sparrow Nestlings and Parental Feeding Behavior

Ecoimmunologists model bacterial infection in free-living animals using lipopolysaccharide (LPS), a macromolecule found in bacterial membranes, but the concentration of LPS varies among these studies. It is unclear what dose triggers a response that is most reflective of the natural avian response to pathogens. Additionally, little is known about how immune challenges may alter parental feeding behavior. To test how the dose of LPS administered to nestlings influences parental provisioning, we injected house sparrow nestlings with either 0, 0.01, 0.1, or 1.0 mg LPS per kg body mass prior to fledging. We conducted behavioral observations three times per nest: 18 h pre-injection, 6 h post-injection, and 30 h post-injection. We observed each nest for one hour and recorded the number and duration of parental visits and sex of the parent during each visit. Preliminary analyses suggest that there were no differences in feeding rate 6 h post-injection in response to LPS doses. However, parental feeding rate after 30 h was higher for nestlings injected with 0 or 1.0 mg LPS per kg body mass than it was for nestlings injected with 0.1 and 0.01 mg LPS per kg body mass. These findings suggest that house sparrow parents alter their feeding rate based on the degree of immune challenge experienced by their nestlings. It is possible that the highest dose initiates a more rapid immune response, which is thus completed more quickly, whereas the lower doses incite a less intense but longer immune response, so nestlings reflect longer-lasting sickness behavior, such as decreased begging. The variability of parental behavior in response to LPS dose in nestlings stresses the importance of using various LPS concentrations in ecoimmunology studies.

P2-58 STILSON, K/T*; ROSS, C; REED, D; The University of Chicago Department of Organismal Biology and Anatomy, The University of Illinois at Chicago College of Dentistry; *kstilson@uchicago.edu*

Periodontal ligament innervation in Didelphis virginiana informs the study of neuronal function and evolution at the Eutherian-Metatherian split

The periodontal ligament (PDL) is a network of unmineralized collagen fibers that connects teeth to alveolar bone, the innervation of which transformed teeth into multimodal sensory structures that transduce and integrate sensations of pressure, vibration, pain, and temperature to the cortex. This evolutionary innovation occurred in concert with other dramatic changes in the orofacial skeleton such as the emergence of heterodont dentition and expanding brain. The metatherian opossum, *Didelphis virginiana*, is a key phylogenetic comparison to the well-studied eutherians because it is an omnivore, heterodont, and retains a PDL. Here we identify and map individual nerve types and locations in the lower first molar of *D. virginiana* using immunofluorescence. Glial and glial-related cells that surround neurons were immunolabeled with S100, SMI 312 and NF-M, and PGP 9.5 and imaged with a confocal microscope. PDL collagens were quantified using picrosirius Red (PSR). PSR revealed that the majority of collagen fibers are oriented in a dorsomedial "sling". Immunolabels showed neurons running dorsoventrally (DV) in neurovascular bundles and parallel to both the alveolar socket and tooth root. Other nerve bundles appear to be Golgi-Mazzoni corpuscles, very thin corpuscles, and free nerve endings. Innervation of the PDL in opossums shows a DV organization more analogous to nerves seen in eutherian carnivoran incisors than in the molars of their omnivorous counterparts. This suggests the last common ancestor of Eutheria and Metatheria, ~150 million years ago, had a conserved PDL structure and DV organized neurovascular structure, the function of which we will be testing in future research.

P1-7 STINSON, CM; California State University, Bakersfield; *cstinson4@csub.edu*

Incorporating Ethics Into Introductory Biology and Human Physiology Curriculum

Working in public forums or in health professions, it is critical to have an understanding of and road map for navigating ethical issues. While teaching courses in Human Physiology and Introductory Animal Biology, I introduced a module to discuss the importance of ethics in our personal and professional lives. Students utilized the Rutland Model to identify ethical issues in case studies and "sticky situations", analyzed why a given situation may involve ethics, justified responses to the issue, and ultimately decided on their course of action. These activities required students to think critically about plausible situations they may encounter in the work place while building on their current knowledge base from the course. Communication skills were enhanced through various group discussions, as well as through a written reflection on the scenarios. Overall, by adding this module to multiple courses students have been able to apply the standard course material to more "real world" situations and have built a foundation to use ethical assessments in their future professions. These activities allow students to become further invested in the material, and because there are often multiple correct answers to the situations proposed, students actively shared their opinions and responses to the scenarios at hand.

50-6 STOCKER, MR*; NESBITT, SJ; KLIGMAN, BT; PALUH, DJ; BLACKBURN, DC; MARSH, AD; PARKER, WG; Virginia Tech, Florida Museum of Natural History, University of Florida, Petrified Forest National Park; *stockerm@vt.edu*

The Earliest Equatorial Record of Anurans: New Fossils from the Late Triassic of Arizona

Crown-group anurans originated more than 200 million years ago, though only a few fossils from high latitudes chronicle the first 60 million years of their evolution and distribution. We report fossils that represent the first anurans known from the Late Triassic, as well as the earliest equatorial record for anurans. These small fossils consist of complete and partial ilia with anteriorly directed, elongate, and hollow iliac blades, unmistakable anuran characteristics. These ilia are more similar to those of crown anurans than to those of their Early Triassic relatives *Triadobatrachus* from Madagascar and *Czatkobatrachus* from Poland, both of which are high latitude records. This series of new anuran fossils demonstrate that anurans were present in the Late Triassic in the equatorial region of Pangea. Furthermore, the presence of anurans in the Early Jurassic in the same stratigraphic sequence (*Prosalirus bitis* from the Kayenta Formation of Arizona) suggests that anurans survived the climatic aridification of this region in the early Mesozoic. This regional anuran survival of the end-Triassic extinction event could have been the result of recolonization or clade turnover. These new fossils highlight the importance of targeted collection of microfossils and provide further evidence for the presence of crown-group representatives of modern orders of terrestrial vertebrates prior to the end-Triassic extinction.

S4-10 STODDARD, M. C. *; LING, L; WEAVER, J. C. ; Princeton University, Virginia Polytechnic Institute and State University, Wyss Institute for Biologically Inspired Engineering at Harvard; *mstoddard@princeton.edu*

The Avian Egg: A Marvel of Evolution and Engineering

The eggs laid by modern birds are the products of more than 150 million years of evolution, resulting in a sophisticated package designed to balance a range of competing demands. The egg must be tough enough to prevent external damage but weak enough to permit a chick to hatch. It must resist bacterial contamination but allow gas exchange between the chick and the outside environment. The egg satisfies these requirements, which is especially remarkable given that it forms in under 24 hours: its calcium carbonate shell is one of the fastest-forming biominerals in nature. From an evolutionary perspective, bird eggs are fascinating because they come in a great variety of shapes, sizes, colors, and structures despite the fact that they serve the same essential function: to nourish and protect a chick until it hatches. What selective pressures influence the diversity of egg phenotypes? From an engineering perspective, eggshell is impressive because it is a strong, lightweight material, yet we understand relatively little about its biomechanical properties outside of chickens. What is the relationship between the structure and function of eggshell? In addition, how do eggs form in the avian oviduct? Here, we explore these questions through the lenses of evolutionary biology, biophysics and mechanical engineering, which together provide an integrative picture of the form and function of avian eggs.

P1-62 STOKES, KA*; DIMITRI SKANDALIS, ; JIMMY LIAO, ; University of Utah, University of Florida; *katieannestokes@gmail.com*

Chronic stimulation during larval zebrafish development affects startle response

In stress disorders such as PTSD, chronic exposure to a threat stimulus results in sensitization or hypervigilance. Much remains unknown about the neurophysiological mechanisms underlying this phenomenon. The genetic tools and robust startle response of the zebrafish make it a tractable model to study the molecular basis of stress-induced behavioral changes. In zebrafish, the lateral line is a structure containing hair cells, sensory receptors that allow the fish to sense the flow of surrounding water. This mediates a startle response wherein a hydrodynamic stimulus is perceived as a threat. The startle response behavior demonstrates an intensity-dependent relationship where the magnitude of the stimulus and latency of response are inversely related. This project aims to explore how the established relationship between the intensity of stimulus and latency is affected by chronic stimulation of the lateral line during early larval development. To test this paradigm, we used transgenic zebrafish containing blue light-sensitive channelrhodopsin-2 (ChR2) in hair cells of the lateral line. Administration of blue light stimulus allowed for remote activation of the lateral line via depolarization of hair cells mediated by ChR2. The latency and probability of startle response were recorded using a high-speed camera. The data showed no significant relationship between the intensity of stimulus and response latency or probability, though significant improvements can be made in experimental design. Although results from this study were inconclusive, further study may indicate a level of developmental neuroplasticity in the mechanosensory system of larval zebrafish and illuminate the neural mechanisms underlying stress-related behavioral response.

P2-222 STORCH, JS*; STAAB, KL; BETANCUR-R, R; HERNANDEZ, LP; The George Washington University, Washington, DC, McDaniel College, Westminster, MD, University of Puerto Rico - Rio Piedras, San Juan, Puerto Rico; *jdstorch@gwu.edu*

Driving the Power Stroke of Premaxillary Protrusion: The Evolution of Diverse Cranial Musculature in Cypriniform Fishes

Cypriniform fishes comprise over 25% of the world's freshwater species. These fish exhibit a suite of morphological novelties--including kinethmoid-mediated premaxillary protrusion, a muscular palatal organ, and the loss of oral teeth--associated with feeding and occupy a variety of trophic niches. Diverse morphology within the trophic apparatus provides a biological model with which we can investigate the evolution of complex systems. Prey capture is effected by protrusion of the premaxilla. Are there as many ways to drive this effector as there are targets? We survey the anatomical diversity of the A1 division of the adductor mandibula muscle in Cypriniformes. We interpret these morphological data using a functional lens to characterize diversity in this element of the trophic apparatus. We use phylogenetic comparative methods to reconstruct the evolutionary history of trophic morphology in cypriniform fishes and to investigate the role morphological diversity plays in supporting trophic diversity across this group. Specifically, we demonstrate the early recruitment of protrusile morphology for post-capture prey processing and transport associated with benthic feeding modes. We expect strict suction performance to be constrained by the integration of protrusile morphology with other functional elements of the trophic apparatus.

47-4 STROTHER, JA*; HANEY, WA; Oregon State University; *james.a.strother@gmail.com*

Identifying the neural encoding of respiratory cues in zebrafish

The nervous system has a central role in the regulation of the cardiovascular and ventilatory systems in vertebrates. Oxygen, carbon dioxide, and arterial pressure in the blood are monitored by sensory neurons including neurons of the glossopharyngeal and vagal sensory ganglia. These sensory neurons project into the hindbrain, where signals are integrated by complex circuits that are still not fully understood. Neurons of the hindbrain then synapse onto preganglionic neurons of the parasympathetic and sympathetic nervous systems, which ultimately innervate the target organs and control heart rate, vasomotor tone, and ventilatory rate. Larval zebrafish are an ideal system in which to examine how cues are encoded by sensory neurons and integrated by hindbrain neural circuits, since their small size and optical transparency enables approaches that are difficult in other animal models. To address these questions, we recorded the responses of neurons of the vagal sensory ganglion in larval zebrafish to a range of respiratory cues including low oxygen and high carbon dioxide. Responses were quantified by expressing the fluorescent calcium indicator GCaMP6F in these neurons, imaging these neurons using in vivo multi-photon microscopy, and taking fluorescence as a measure of neural activity. We found that individual cells exhibited characteristic profiles in their response to different cues.

P1-195 STROUD, C/S*; HIBBERTS, S/J; JEANES, R/C; SMITH, K/M; CHILDRESS, M/J; Clemson University; *csstrou@clemson.edu*

Responses of Transplanted and Natural Coral Colonies to Thermal Stress Events

Climate change threatens coral reefs with elevated water temperatures triggering bleaching events that lead to increased mortality. In response to the decline in coral cover, researchers have transplanted coral colonies to better understand which species are best adapted to these environmental changes. In this study, we examined the impacts of two thermal stress events on both transplanted and naturally occurring coral colonies in the middle Florida Keys. We tagged 16 naturally occurring coral colonies and transplanted an additional 68 colonies of two coral species (*Porites astreoides* and *Siderastrea siderea*) on seven reef sites. We monitored these colonies for evidence of coral bleaching (discoloration) from June 2013 through June 2017. Our results indicate that *P. astreoides* colonies are more susceptible to bleaching (71%) than *S. siderea* colonies (9%). We also found site specific responses, with colonies on some sites remaining unbleached. However, we did not find significant differences between the responses of transplanted and naturally occurring colonies, with similar numbers of each being resistant. These findings suggest that while certain species are better prepared for increases in sea surface temperatures, coral survival may depend strongly on local adaptations to reef location.

116-3 STRUBLE, MK*; DONATELLI, C; STANDEN, E; GIBB, A; Northern Arizona University, Tufts University, University of Ottawa; *strublemikayla@gmail.com*

Burial Behavior in Elongate Fishes of the Salish Sea

Multiple groups of fish have evolved burial behavior, and there are a range of biomechanical mechanisms that enable differently shaped fishes to bury into the substrate. We examined fishes currently classified as Zoarcoids, suborder Zoarcoidei, a group that includes several elongate families of fish, including the Zoarcidae (eelpouts), Pholidae (gunnels), Anarhichadidae (wolffishes), and Steicheidae (pricklebacks). These fishes often live in near-shore or intertidal regions where they navigate complex environments, populated by seagrasses and rocks. Some species within Stichaeidae and the closely-related Pholidae are known to remain above the water line during low tides, where they remain hidden beneath rocks and gravel, while other Stichaeid and Pholid species remain in subtidal zone and do not naturally bury. To observe and quantify burial behavior in these elongate fishes, we collected individuals representing five species found in the Salish Sea (San Juan Island, Washington), performed a behavioral analysis, and compared burial biomechanics among different species. We documented disparities in burial tendencies, which suggests that while some fishes that are reluctant to bury into the substrate may lack the ability to bury because of some as-yet-unidentified aspect of their morphology, other fishes are biomechanically capable of burial but are not behaviorally inclined towards burial which may suggest a relatively recent behavioral shift in habitat preferences. We found that elongate fishes can bury themselves using a variety of behavioral processes, two of which have not previously been described in fish. We also note that, although elongate fish burial-behavior shares similarities with both terrestrial and aquatic locomotion, it possesses features which are not present in either and represents a unique mode of locomotion in elongate fishes.

60-7 STUBBS, RL*; FOLK, RA; SOLTIS, DE; CELLINESE, N; University of Zurich, University of Florida; *stubbsrl@ufl.edu*
Phylogenomics Resolves Relationships within an alpine-Artic plant clade (Micranthes, Saxifragaceae) and Reveals Evolutionary Processes and Historical Biogeography
Flora endemic to the cold habitats of the Northern Hemisphere, i.e., mountains and Arctic, provide important models for investigating diversification and disjunctions, given both the intense climatic fluctuations that have occurred during the Quaternary and the fascinating biogeographic patterns found in these regions. *Micranthes* (Saxifragaceae), a clade of small-flowered herbs comprising 80 species, is an ideal group for investigating the evolution and diversification of plants in montane and Arctic ecosystems, which are especially vulnerable to climate change. Over one-third of all species of *Micranthes* are cold-adapted—in comparison to only four percent of all known vascular plant species—suggesting that this group is specialized for these conditions. This assumption is further supported by the fact that many of the cold-adapted *Micranthes* have a suite of specialized morphological and reproductive traits not seen in low-elevation and low-latitude species of this clade, including leaf succulence, strongly asymmetric corollas, and asexual reproduction through bulbils. This research explores the evolution and geographic spread of cold-adapted plants through both phylogenomics using *Micranthes* as a model. This goal was accomplished by reconstructing a time-calibrated phylogeny based on hundreds of low-copy nuclear markers, and in conjunction with a phylogeny reconstructed from the majority of the plastome. These genes were analyzed in multiple downstream analyses to elucidate the patterns of diversification in this group. Together, these investigations provide insights into speciation and biodiversity at multiple spatial and phylogenetic scales.

P2-2 STUBBS, RL*; THEODORIDIS, S; KELLER, B; CONTI, E; University of Zurich, University of Copenhagen; *stubbsrl@ufl.edu*
The evolutionary roles of hybridization and introgression: investigating species and genomic boundaries using the model plant system Primula (Primulaceae)
Studies have suggested that parts of the genome are differentially affected by introgression as a result of hybridization, with some regions being resistant to gene flow while others are exchanged freely between related species. However, distinguishing between differential introgression and evolutionary processes, such as incomplete lineage sorting, historical gene flow, and genetic drift, that equally shape the heterogeneous genomic landscape requires the integration of both macro- and micro-evolutionary approaches, but studies are limited. To address this gap, we present the largest, most inclusive study, using the model plant system *Primula* (Primulaceae). This is being accomplished through extensive sampling spanning the entire range of our study system (~660 individuals in seven species), in conjunction with resequencing of whole genomes utilizing the high quality reference genome currently available within of study system (*P. veris*). Our downstream analyses will include both phylogenomic analyses (e.g., RAxML, ASTRAL, SNAQ, PhyloNet) and inference of ancient gene flow (ABC, ADMIXTURE). As a result of intensive sampling at multiple temporal (from phylogenomic to population genomic) and geographic scales (from allopatric to sympatric comparisons), replicate comparisons between species pairs with different strengths and directionality of crossability and reproductive isolation, and availability of a reference genome and linkage maps in the model system this research will generate new knowledge on the genomics of hybridization at levels of resolution unprecedented in plants. In total, this research will provide innovative contributions to the growing field of hybridization and speciation studies.

7-4 STUBBS, A. L.; Univ. of California, Berkeley; *astubbs@berkeley.edu*
Sound attributed to "sonic attacks" on U.S. diplomats in Cuba spectrally matches echoing cricket
Staffing at the United States Embassy in Cuba was greatly reduced following a potential "sonic attack" on U.S. personnel. The sound linked to these attacks was recorded by U.S. personnel and released by the Associated Press (AP). The call of the Indies short-tailed cricket (Anurogryllus celerinictus) matches the recording in duration, pulse repetition rate, power spectrum, and pulse rate stability yet the temporal pulse structure in the recording is unlike any natural insect source. When the cricket call is played on a loudspeaker and recorded indoors, the interaction of reflected sound pulses yields a recording virtually indistinguishable from the AP sample. This provides strong evidence that a cricket rather than a "sonic attack" or other technological device is responsible for the sound in the released recording.

P1-197 STUDIVAN, MS*; VOSS, JD; Florida Atlantic University, Harbor Branch Oceanographic Institute; *mstudiva@fau.edu*
Mesophotic-omics: Integrating Transcriptomics, Transplants, & Algal Symbiosis to Understand Coral Adaptation in the Gulf of Mexico
Coral habitats are highly abundant in the Gulf of Mexico, including mesophotic coral ecosystems between 30-150 m, but there is a lack of understanding regarding the ecological roles of mesophotic corals & the functional differences among depth-generalist conspecifics. We designed an integrative approach examining transcriptomics, morphometrics, & algal endosymbionts to quantify natural variation of shallow & mesophotic *Montastraea cavernosa* colonies. RNA-Seq profiling was conducted across 4 sites with shallow & mesophotic habitats in the Gulf of Mexico & Caribbean, including Belize, Flower Garden Banks, Pulley Ridge, & Dry Tortugas. Variability across regions was a stronger driver of coral gene expression compared to differences between depth zones within regions. Metabolic gene pathways were consistently under-expressed at depth, while cell division pathways were highly expressed & may reflect increased algal symbiont density in mesophotic corals. Additionally, transplant experiments at the Flower Garden Banks identified plastic gene expression within 6 mo. after relocation across depth zones. During a bleaching event at 12 mo., we observed lower stress resilience in transplants from mesophotic to shallow depths as compared to shallow controls. However, gene expression during bleaching suggested potential metabolic & symbiont recovery in transplants and was corroborated by follow-up observation at 36 mo. This integrative study provides a better understanding how variation in gene expression can contribute to corals' flexibility in different environments. Knowledge of coral adaptation to light-limited environments can improve predictions regarding the roles mesophotic coral ecosystems may play in survival of shallow coral reefs.

68-4 SULLIVAN, CM*; CARR, JA; TYTELL, ED; Emmanuel College, Salem State Univ., Tufts Univ.; *sullivanc@emmanuel.edu*

Muscle response to lengthening and shortening perturbations at various activation and perturbation phases.

During locomotion, animals often must cope with unexpected forces. These perturbations may cause an increase or decrease in length of their muscles. Although animals may sense these perturbations and change the way they are moving to compensate for them, the muscles themselves, separately from the nervous system, may help to compensate for perturbations. I investigated how brief shortening and lengthening perturbations at different phases affect muscle force during sinusoidal length changes. Muscle samples from silver lampreys (*Ichthyomyzon unicuspis*) were studied using a modified work loop protocol, in which small lengthening and shortening perturbations were added on top of an overall sinusoidal oscillation. While being lengthened and shortened at 1Hz, the muscle was activated electrically at four phases. We also applied lengthening or shortening perturbations at four phases. During each perturbation, we estimated the maximum force, stiffness and damping of the muscle. We compared these quantities between lengthening and shortening perturbations. We also compared how the muscle segment returns to its baseline oscillation after each perturbation. For both types of perturbations, if the perturbation is applied while the muscle is being lengthened, the forces are high . If the perturbations are applied during shortening, the forces are lower. Moreover, when the muscle segment is relatively short, the damping response is stronger than the elastic response. Overall, we find that muscle responds differently to lengthening and shortening perturbations, and the response depends on both activation and perturbation phase.

48-7 SUMMERS, A.P.*; BLOB, R.W.; BUTLER, M.A.; FARMER, C.G.; FASSBINDER-ORTH, C.A.; HERNANDEZ, L.P.; MOORE, I.T.; MULLER, U.K.; SATTERLIE, R.A.; WILLIAMS, S.H.; SUMMERS, Adam; Friday Harbor Labs, Clemson University, University of Hawaii, Trinity College, Dublin, Creighton University, George Washington University, Virginia Tech, CSU Fresno, UNC-Wilmington, Ohio University; *fishguy@uw.edu*

Integrative Organismal Biology - a journal of the Society for integrative and Comparative Biology

We are excited to announce the launch of Integrative Organismal Biology, an open access journal that will serve as an organizing center for our field. Recent efforts to define grand challenges have made clear the need to integrate across disciplines that form modern organismal biology. SICB has flourished, demonstrating there is a critical mass of biologists who value and benefit from the diversity of thought and approaches that span the society's divisions. There is a pressing need for an intellectual outlet that showcases our best integrative endeavors. For example, we have comparative endocrinologists fundamentally interested in the ecology and evolution of their study organisms, neurobiologists working on the biomechanics of feedback systems, and physiologists making advances in behavior and ecology. *Integrative Organismal Biology (IOB)* will give structure to the broad field and serve as a signpost for funding agencies, foundations, and national policy discussions. *Integrative Organismal Biology* will define and push the edges of integrative and comparative biology, putting it on stage with, and complementing, more reductionist and abstract flavors of biology. IOB will be: (1) explicitly and fundamentally integrative; showcasing work that is broader than a typical disciplinary journal; (2) open-access; and (3) a voice for diverse authors through inclusive and empowering policies, including double-blind peer review, and an explicitly constructive peer review process.

P2-101 SUMMERS, R.R.*; BAKER, D.M.; University of Mary Washington; *rsummers@mail.umw.edu*

Embryonic Development of the Stress Hormone Axis in Two Model Teleost Species

Glucocorticoid hormones mediate stress responses in all vertebrates, from teleost fishes to mammals. In teleosts the primary glucocorticoid, cortisol, is synthesized by the interrenal gland via a series of enzyme-mediated reactions. Cortisol synthesis in adults is controlled by hormones produced via the hypothalamic-pituitary-interrenal (HPI) axis in response to stressors. The hypothalamic peptide corticotropin-releasing hormone (CRH) stimulates release of the pituitary protein adrenocorticotropin hormone (ACTH), which stimulates interrenal cortisol production. Cortisol exerts its effects on target cells via two types of receptors, the glucocorticoid receptor (GR) and mineralocorticoid receptor (MR). The timing and sequence of events that leads to a functioning HPI axis in developing teleosts are not fully known. To address this gap, we measured the mRNA from genes involved in cortisol synthesis and signaling throughout embryogenesis in two model fishes, the zebrafish (*Danio rerio*) and Japanese medaka (*Oryzias latipes*). We isolated RNA from embryos collected at multiple developmental stages in both species, and used qPCR to measure relative mRNA levels of key HPI axis genes, including CRH, steroidogenic acute regulatory protein (StAR), and MR. In zebrafish, MR transcript levels remained fairly constant throughout embryo development, whereas in medaka, MR transcripts increased 10-fold. Zebrafish CRH mRNA doubled from 6 hours post fertilization (hpf) to hatching (48 hpf). However, in medaka, CRH mRNA levels rose over 90-fold from 2 days post fertilization (dpf) to hatch at 8 dpf. In zebrafish, StAR mRNA levels increased 40-fold from 24 hpf to hatch, whereas levels rose only 5-fold in medaka. In conclusion, we found noteworthy differences in mRNA profiles for CRH, MR, and StAR in both species.

57-1 SUR, A*; RENFRO, A; MEYER, NP; Clark University, Worcester, MA; *asur@clarku.edu*

Investigating cellular and molecular mechanisms of neurogenesis in the annelid Capitella teleta

Evolution of nervous systems (NSs) has been an enigma. NS architectures vary widely across Metazoa. Such diversity relies on the developmental mechanisms controlling neurogenesis i.e. the generation of neurons from neural precursor cells (NPCs). Similar genes regulate neurogenesis in some ecdysozoans, deuterostomes, and cnidarians; however, there are similarities as well as differences in how certain neurogenic homologs are deployed across clades. For example, NPCs maintain their proliferative state via upregulation of SoxB1 factors in both vertebrates and insects. In contrast, proneural homologs (e.g. Achaete-Scute and Neurogenin) promote fate specification of NPCs in insects but induce cell-cycle exit and differentiation in vertebrates. Neurogenesis is largely unexplored in the third major bilaterian clade, Spiralia, and spiralian data would enable better reconstruction of NS evolution. We examined neurogenesis in the spiralian annelid *Capitella teleta* using fluorescent in situ hybridization and pulse-chase labeling with the thymidine analogs EdU and BrdU. In *C. teleta*, apical neuroectodermal cells express homologs of *soxB1*, *neurogenin* and *ash* while basal cells express neuronal markers like *elav1* and *synaptotagmin*. We identified the spatial localization of proliferating cells within the developing neuroectoderm and correlated that with marker gene expression in order to better understand the progression of neurogenesis in *C. teleta*. Moreover, we also examined co-expression of neurogenic homologs to understand possible co-regulation within a gene regulatory network. Our data indicate a hierarchical regulation of these genes in a manner similar to that in insects and future gain- and loss-of-function studies will test these relationships.

P3-176 SURBAUGH, KL*; ROHR, JR; University of South Florida; *ksurbaugh@mail.usf.edu*

Assessing acquired resistance of the adult Cuban Treefrog (Osteopilus septentrionalis) to the pathogenic chytrid fungus (Batrachochytrium dendrobatidis)

Emerging fungal pathogens have been proposed to be the greatest threat to biodiversity over other parasitic groups. Batrachochytrium dendrobatidis is an infectious fungal pathogen of the chytridiomycete class which has been found to be a contributing factor to hundreds of amphibian species extinctions worldwide. Because amphibians have illustrated an ability to acquire resistance to Bd, inducing resistance via treatment with flash-frozen, dead Bd may be the key to protecting susceptible populations. To determine the dose and duration of exposure necessary to induce resistance, we manipulated the duration and dose of exposure of adult frogs to dead Bd using a 5x5 response surface experimental design in the laboratory that includes the full vertical and horizontal dose and duration gradients and the four corners of the treatment matrix so that we test 13 of the 25 possible treatments. We exposed Cuban tree frogs (Osteopilus septentrionalis) to 5 levels of dead Bd, as well as a control, every other day for 1, 2, 3, or 4 weeks. After the exposures, we exposed all frogs to live Bd (1ml of 1x106 zoospores/ml) and maintained them at 18°C for two weeks in an environmental chamber. Frogs were swabbed and Bd burdens quantified by estimating the density of zoospores using a StepOne Real-Time PCR System. We hypothesize assessment of infection intensity by dose and duration will provide this missing information needed for conservation efforts.

S3-10 SUTTON, GP; University of Lincoln; *RScealai@gmail.com*

The two Borelli laws for jumping animals

Borelli's law is 500 year-old constraint on how high an animal can jump. The argument is simple, as animals get larger, their ability to generate mechanical energy and their mass both go up at the same rate. Consequently, the net height of the jump (related to the energy divided by the mass) is independent of size. We will show that the available energy density per mass, however, is different depending on the underlying biomechanics of the jump - animals that generate a jump with muscle contractions approach a different energy density limit than animals that power their jumps with spring loaded power amplification systems. There are thus two 'Borelli's laws', one for muscle powered jumpers and one for spring driven jumpers. Which of these two laws an animal follows is a consequence of its size, with it being much more energy efficient for large animals (mass greater than 1 kilogram) to power their jumps with direct muscle contraction, while it is more energy efficient for small animals (mass smaller than 1 gram) to power their jumps with springs. I will show where these two energy limits are, the underlying principles that cause these limits, and how these limits constrain the jumping heights of various sized animals. Excitingly, frogs (which exist in the mass range between 1 gram and 1 kilogram) exist in a 'half way' zone between these two biomechanical size limits, providing an intermediate kind of jumping mechanism: 'direct muscle contraction enhanced by a power amplifying spring'.

37-8 SWAFFORD, AJM*; OAKLEY, TH; UC Santa Barbara; *andrew.swafford@lifesci.ucsb.edu*

Insights into Early Sensory Evolution from Sensorimotor Systems in Unicellular Zoospores of a Fungus

Complex sensory suites often underlie critical questions in organismal biology because of their profound influence on the ecology and evolution of species. However, the majority of sensory system research has been focused only on animals leaving questions about early sensory system evolution, which require broad comparative frameworks, unanswered. To better understand the evolution and integration of early sensory systems we have turned to the 'early diverging lineage' of fungi, which include the Blastocladiomycota. These fungi have retained a single-celled propagule called a zoospore. They are highly motile, diploid cells that use either phototaxis or chemotaxis to control their swimming. Here, we describe the first multimodal sensorimotor system in fungi, simultaneously integrating light and chemical cues to control dispersal and settlement in unicellular zoospores. We find that only the zoospores of *Allomyces arbusculus* exhibit both phototaxis and chemotaxis, and that closely related *Allomyces* species do not share this multisensory system. This diversity of sensory modalities within *Allomyces* provides a rare example of a genus showing rapid sensory system evolution in response to the gain or loss of individual senses. Taking advantage of this newfound framework, we use pharmacological knockdowns to reveal that multisensory systems in *Allomyces* co-opt new ion channels in order to integrate novel senses into existing behaviors. These studies into zoospore biology reveal deceptively complex sensory systems and variation hidden in these previously unassuming unicellular fungi. Understanding how these systems evolve and contribute to diversification is a step towards a deeper understanding of how organisms perceive, interact, and adapt to their environments.

P2-273 SWAFFORD, AJM*; OAKLEY, TH; UC Santa Barbara; *andrew.swafford@lifesci.ucsb.edu*

Opsin Family Macroevolution and the Origin of Light Sensitivity in GPCRs

Illuminating the origins and evolution of vision in animals hinges on understanding the evolution of the underlying gene families. The most crucial of these genes is the photosensitive G-protein coupled receptor (GPCR), Opsin. GPCRs are a family of diverse sensory and signaling proteins, and until recently, Opsins were thought to be the only light sensitive GPCRs. This hypothesis was supported by an ultra-conserved lysine found in all functional Opsins. The lysine allows the Opsin to bind a chromophore that induces signaling when it absorbs a photon. However, recent studies hypothesized that there are alternate binding sites also capable of facilitating retinal binding. If these binding sites exist in non-Opsin GPCRs, we must change the way we think about the origins and evolution of vision in animals. However, support for alternate binding sites in GPCRs is scarce, with only a single publication showing evidence of functional light sensitivity outside of Opsins. Here, we construct a phylogeny of GPCRs and reconstruct ancestral states to show that light sensitivity in GPCRs likely first evolved at the ancestor of Opsins and not before. However, we also find at least thirteen other independent origins of a putative light-sensitive alternate site across non-opsin GPCRs. Additionally, we investigate the broader question of how the emergence of image forming vision effects Opsin family evolution. We find that Opsins involved in image formation maintain duplicate copies at a higher rate when associated with a yet unknown character. Our results suggest that light sensitivity may have evolved multiple times within GPCRs and that Opsins emerged early as a specialized and efficient photosensor.

P2-130 SWAIN, K. C.*; LANE, Z.; ZARDUS, J. D.; The Citadel, Univ. S. Mississippi; *kswain@citadel.edu*

Barnacles in Motion: A New Method for Rearing and Maintaining Barnacles in the Laboratory

Sea turtle barnacles (*Chelonibia testudinaria*) develop through multiple larval stages in the plankton. At the final cyprid stage, the larvae search for a suitable substratum on which to settle, metamorphose, and grow into adulthood. While the larvae of many barnacle species have been successfully reared and settled in the laboratory, there has been little attention or success in maintaining adult stages *ex situ*. To address this gap and make possible studies on live adults of largely inaccessible barnacle species, we devised two apparatuses utilizing rotating PVC pipes to facilitate barnacle attachment and growth, the settlement-promoting 'larvulator' and a grow-out tank, the 'maturation spinner'. The larvulator operates by a motor driven, double gear system that rotates a rack of six concurrently revolving pipes within a circular chamber; whereas, the maturation spinner employs a belt and pulley system to spin pipes about their central axis, upright in a standard table-top aquarium. Each device operates on the principle of generating the effects of flow in a static chamber without needing to pump water. In the case of the epibiotic barnacle *C. testudinaria*, the PVC pipes serve as a synthetic mobile host, moving through the water. We demonstrate that these devices can be used to achieve larval settlement and growth with *C. testudinaria*. Settlement rates of this species on PVC pipes was consistently low relative to the quantity of larvae supplied, but typical settlement rates for this species remains unknown. Growth rates were similar or reduced relative to wild populations, but we were able to maintain adults on pipes in excess of two years. Increased understanding of larval and adult barnacle diets may improve outcomes but our methodology presents a viable way to grow adult barnacles in the laboratory.

P3-124 SWALL, M.E.*; BENRABAA, S.A.; MYKLES, D.L.; Colorado State University; *mswall@rams.colostate.edu*

Characterization of Shed genes in the molting gland (Y-organ) of the land crab, Gecarcinus lateralis

Molting in decapod crustaceans is controlled by ecdysteroid hormones synthesized and secreted by the molting gland, or Y-organ (YO). Halloween genes encode cytochrome P450 enzymes in the ecdysteroid synthetic pathway. The current paradigm is that YOs secrete inactive precursor (e.g., ecdysone), which is hydroxylated at the #20 carbon to active hormone (20E) by a cytochrome P450 20-hydroxylase in peripheral tissues. 20-Hydroxylase (*CYP314A1*) is encoded by *Shed* in decapods and *Shade* in insects. We used spiny lobster *Shed* sequences to extract and characterize orthologs in the *G. lateralis* YO transcriptome. Six contigs encoding *Shed* sequences were identified. Analysis of RNA-Seq data from animals induced to molt by multiple limb autotomy showed that *Gl-Shed3* and *Gl-Shed4* mRNA levels were highest in intermolt and lowest in postmolt animals. mRNA levels of *Gl-Shed2* and *Gl-Shed5* were highest in premolt and lowest in postmolt. Activin/Transforming growth factor beta (TGF&beta) signaling is responsible for transitioning the YO from activated state in early premolt to committed state in mid premolt. qPCR was used to quantify the effects of SB431542, an inhibitor of TGF&beta signaling, on mRNA levels in YO from control and experimental animals induced to molt by eyestalk ablation (ESA). ESA increased *Gl-Shed5* mRNA level and decreased *Gl-Shed6* mRNA level in control animals at 14 days post-ESA. SB431542 lowered *Gl-Shed2* and *Gl-Shed3* mRNA levels relative to those in controls at 14 days post-ESA, while SB431542 had no effect on *Gl-Shed1*, *Gl-Shed4*, *Gl-Shed5*, and *Gl-Shed6* mRNA levels. *Shed* genes were expressed in all tissues examined. These data suggest that the YO is capable of secreting active ecdysteroid. Future work will determine whether the YO can synthesize and secrete 20E *in vitro*.
Supported by NSF (IOS-1257732).

61-5 SWIDERSKI, DL*; ZELDITCH, ML; Univ. of Michigan, Ann Arbor; *dlswider@umich.edu*

Divergence Deferred: Dynamic Changes in Ecological Opportunity Produce a Late Burst Radiation in Ground Squirrels

Unlike early bursts, late bursting radiations have an initial shift to a new adaptive zone followed by a long quiescent period before diversity or disparity begin to increase. This late burst pattern challenges the notion that ecological opportunity giving access to the adaptive zone makes the entirety of zone available in one stroke. In the squirrel subfamily Xerinae, one lineage remained arboreal and retained the arboreal diet and two lineages shifted from arboreal to terrestrial habits, adopting novel diets that required less gnawing and more mastication; all three invaded new continents. We examine the influence of these ecological and geographic transitions on the evolution of mandibular size and shape. The arboreal one exhibits an early burst in size and shape, but neither terrestrial lineage follows this pattern. Both terrestrial lineages diverge from tree squirrels in shape preceding their invasion of new continents. One, invading Africa, undergoes little additional change in size or shape. The other, invading North America, undergoes a large initial divergence (separating chipmunk and ground squirrel lineages) but no further change until ground squirrels undergo late bursts of size and shape more than 10 Ma later. The timing of morphological divergence in North American ground squirrels corresponds closely to the timing of grassland expansion on that continent. These results suggest that subdividing the ground squirrel adaptive zone may not have been possible until the grasslands, themselves, expanded and diversified. When ecological opportunity arises from new trophic relationships, the evolutionary pattern of the consumer may depend on that of its new dietary resources.

141-3 SWITZER, C.M.*; DANIEL, T.L.; Univ. of Washington; *callin.switzer@gmail.com*

Fear of Missing Out (FOMO): How bees weigh exploration vs. exploitation of pollen sources

What factors determine where animals choose to forage in the face of uncertain food rewards? Foragers face a challenging problem - visit the best known location or explore new locations where rewards are uncertain. Though theoretical approaches suggest that foragers may decrease exploration over time, few experiments have explicitly examined animals' strategies in uncertain environments. Of the experiments that have been conducted, many allow foraging insects to visit flowers to collect nectar. Though many insects require both nectar and pollen to survive, pollen-foraging is understudied. Bumblebees provide an ideal system to study pollen-foraging, because their pollen-collecting behavior (floral sonication) can be easily quantified. They vibrate their flight muscles to shake pollen from flowers, suggesting that floral sonication is likely more energetically costly than nectar foraging. Using accelerometers, we built an automated system to quantify bees' transitions between flowers - one flower delivered pollen when sonicated and another did not. We found transitions between the two flowers were rare (initially 5-10%). Over time, however, the chance of transitioning from the unrewarding flower to the rewarding flower increased (from 9% to 27%), and the probability of staying on the unrewarding flower decreased (from 89% to 72%). Bees did not visit the rewarding flower exclusively but maintained a constant ~6% chance of transitioning away from the rewarding flower (i.e. exploring the environment). This may be an adaptive strategy to keep bees from missing out on flowers that release pollen at different times of the day or to keep bees from continuing to visit flowers that are releasing diminishing resources. Overall, this work fills a knowledge gap, to help us understand how pollinators make decisions when foraging for pollen as they gain experience in an uncertain environment.

P3-50 SWITZER, C.M.*; BUSTAMANTE, J.; DANIEL, T.L.; Univ. of Washington; *callin.switzer@gmail.com*

Learning a non-linear controller for insect flight dynamics with a deep neural network

Insect flight is a highly non-linear dynamical system. As such, strategies for understanding control have typically relied on either simulation methods (e.g., Model Predictive Control (MPC), genetic algorithms) or linearization of the dynamical system. Here we develop a new framework that combines MPC and deep learning to create an efficient method for solving the inverse problem of flight control. We used a feedforward, fully-connected neural network to answer the question, "What is the temporal pattern of forces required to follow a complex trajectory?" Combining neural networks with simulations based on dynamical systems models yields a data-driven controller where the data are derived from a non-linear physical model. We first trained a deep neural network (4 hidden layers, with hundreds of nodes) on ~8 million simulated 2D insect trajectories. Our network accurately predicted the force, force angle, abdomen angle, and tangential and angular velocities (7 outputs), when it was provided with initial conditions and a goal location (12 inputs). The coefficient of determination (r^2) for all predictions was > 0.999 on a validation dataset (1 million additional trajectories). Next, we evaluated the neural network's ability to control a simulated insect. We used the aforementioned predictions and compared the final conditions generated to simulations. Again, we found that network-prescribed final conditions were nearly identical to numerically solved conditions (r^2 > 0.999). Overall, this work shows that machine-learning may be an efficient approach for controlling nonlinear dynamical systems.

P2-162 SYKES, B.E.*; BALENGER, S.L.; University of Mississippi; *besykes@go.olemiss.edu*

The effects of nest heat manipulation on development, physiology, and parasitism in the eastern bluebird (Sialia sialis)

Selective pressures produced by climate variability have led to differential thermal tolerances amongst animal species. Endothermic animals expend large amounts of energy maintaining their body temperature, and the critical temperatures (maximum highs and minimum lows) that they are able to tolerate depend largely upon the geographic range that they evolved in. When temperatures become unfavorable, adaptations that allow organisms to respond plastically provide an advantage. Those unable to physically migrate must deal with elevated heat metabolically. Altricial nestling birds, which are born naked and unfeathered, cannot maintain their own body temperature until their feathers grow in, and are essentially ectothermic in the early stages of their development. While in the nest, their growth, body condition, and immune response are directly linked to the microclimate in which they are raised. Factors that disrupt their development, then, can be costly. By experimentally manipulating the temperature of nest boxes, I am quantifying a response to heat in eastern bluebird *(Sialia sialis)* nestlings using heat-shock protein 70 as a biomarker for physiological stress. Heat-shock protein 70 is constitutively expressed at baseline levels, but is upregulated under high temperatures. The effects of high HSP70 levels are not known, but there are implications for reduced lifespan and changes in immune effects in other organisms. I am also measuring changes in body condition as well as differing loads of a parasitic bacteria that degrades feathers and thrives under a temperature optimum. Parasites often impose a cost to physical condition, so any observed changes in growth rate under heat must also be examined in relation to parasite load.

103-1 TACK, NB*; DU CLOS, KT; GEMMELL, BJ; University of south florida; *ntack@mail.usf.edu*

Exploring the Benefits and Limitations of Eel-like Swimming

Eel-like locomotion is generally regarded as a metabolically efficient mode of swimming due to the low cost of transportation (COT) observed during steady swimming. Key to this efficiency is the ability to exploit pressure gradients that passively generate sub ambient pressure fields that enhance forward thrust along most of the length of the body. However, a major drawback of anguilliform locomotion is its inability to perform as adequately at velocities greater than 1 body length per second (BL s^{-1}). This suggests that in addition to physio-morphological constraints the mechanical limitations of this mode of locomotion are driven by complex animal-fluid interactions. We assess the relative contribution of both reactive and sub-ambient suction forces at different speeds to identify the limiting factors of eel-like locomotion. Measurements of metabolic activity, swimming kinematics and non-invasive pressure fields were made for steady swimming coral catfish (*Plotosus lineatus*). High-speed, high-resolution particle image velocimetry (PIV) and respirometry data was collected using a modified 5L Brett-type swim tunnel. They revealed the influence of distinct body kinematics on the formation of flow structures along the body that result in a low COT at speeds of 0.5-1.0 BL s^{-1} and higher COT at velocities outside this range. During efficient swimming, two protovortices are always present and retained along the body at a given moment and may allow suction forces to dominate over reactive forces. Although such flow structures were also observed at higher swimming speeds, increased anterior lateral displacement of the body and posterior lateral velocity may result in the presence of dominant reactive forces. These lateral losses in kinetic energy may eventually result in no net acceleration of the fish and thus render anguilliform locomotion impractical.

19-2 TAFF, CC*; ZIMMER, C; VITOUSEK, MN; Cornell University; *cct63@cornell.edu*

Plumage Manipulation Alters Social Interactions and Reproductive Success in Female Tree Swallows

Signals that mediate repeated social interactions have the potential to drive dynamic feedback between signaling phenotype, physiology, and the social environment. In gregarious species, social interactions are ubiquitous, but the consequence of each individual interaction is probably quite small. Thus, for signals that mediate the frequency or nature of repeated interactions, costs and benefits likely arise through the accumulation of many minor interactions. Tree swallows are semi-colonial breeders and are gregarious throughout the year. We previously found that the brightness of the white breast feathers in female tree swallows is correlated with nest visitation patterns, corticosterone levels, and stress resilience. Based on these results, we hypothesized that integration of this suite of traits might be maintained by the experience of repeated social interactions that are mediated by signaling. In this study, we experimentally dulled female breast feathers during the breeding season. Using a network of RFID readers installed at each nest box, we identified ~40,000 instances of an individual visiting a box at which they were not part of the breeding pair. Relative to controls, dulled females had significantly more repeated female visitors at their box but significantly fewer male visitors and these effects persisted throughout the breeding season. As a result of color manipulation, dulled females fledged significantly more offspring at their own nest despite having similar clutch sizes and initiation dates as control females. At this time, the mechanism resulting in increased fitness is unclear, but is consistent with reduced harassment by males and increased investment in breeding effort as a response to the altered social environment that females experienced.

107-6 TAFT, NK; University of Wisconsin -Parkside; *taft@uwp.edu*
Tiny Earth: A new model for laboratory-based undergraduate courses
The Tiny Earth network is a new model that I have recently incorporated into my research-based laboratory course for sophomore undergraduates, Research Process in Biology. The Tiny Earth model is based on a network of instructors and students that are crowdsourcing antibiotics from the soil. This allows instructors and students to develop original research projects that have the potential to address the real-world problem of increased antibiotic resistance. Students work in pairs to develop original, testable hypotheses about how to test soil for new antibiotic-producing microbes from local soils. As a vertebrate morphologist, the prospect of crowdsourcing antibiotics from the soil was a bit daunting, but the benefits have far outweighed the cost of the learning curve. I used the Classroom Undergraduate Research Survey (CURE) survey to measure the learning gains of the students in this course to national means for students participating in similar courses or more traditional mentored undergraduate research projects. While the sample size is small, students in the course had comparable or higher learning gains to national means in several key areas including: skill in interpretation of results, readiness for more demanding research, understanding the research process, tolerance for obstacles faced in the research process, ability to integrate theory and practice, understanding how scientists work on real problems, ability to analyze data and other information, ability to read and understand primary literature, clarification of a career path, understanding that scientific assertions require supporting evidence, and learning to work independently. The Tiny Earth model is an excellent way to provide more undergraduate students with high-impact original, laboratory-based research experiences, particularly at smaller, primarily undergraduate research institutions with more limited resources.

P1-99 TAMONE, SL*; DEAL, CK; FESTER, M; LEVY, T; MANOR, R; SAGI, A; University of Alaska Southeast, Ben Gurion University of the Negev; *sltamone@alaska.edu*
Development of an enzyme-linked immunosorbent assay for Northern spot shrimp Pandalus platyceros vitellogenin and its application for studies into sexual differentiation
Vitellogenin (Vg) is a protein synthesized and secreted from the hepatopancreas of crustaceans during ovarian maturation. Vg is taken up by ovaries during maturation and is modified to vitellin (Vn); it is the yolk-protein that will nourish the developing embryos. We purified Vg and Vn from the Northern spot shrimp (*Pandalus platyceros*) in order to develop 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 functional male to a much larger adult female. Polyclonal antibodies were generated by a commercial vender against vitellogenin/vitellin that was previously purified from homogenates of ovaries obtained from mature adult female shrimp. Western blot analysis demonstrated that the immune serum specifically recocnized the Vn from *P. platyceros* ovarian homogenate and Vg from female but not male *P. platyceros* hemolymph. The standard curve was linear over a range of 75 to 1,800 ng/ml. The Vg ELISA will be used to assess the reproductive physiology of *P. platyceros* as they transform from males to females through a transitional phase. We hypothesize that the hormone that regulates male morphology and physiology (insulin-like androgenic hormone (IAG)) is no longer expressed in *P. platyceros* undergoing the male to female transition. The ELISA will be used in experiments in which the IAG gene is silenced by injection of males with double stranded RNA specific to IAG. Vg will be quantified in hemolymph samples from IAG silenced male and controls.

138-4 TANAKA, H*; KAWAHARA, A; AIZAWA, M; YAMASAKI, T; Tokyo Institute of Technology, Yamashina Institute for Ornithology; *tanaka.h.cb@m.titech.ac.jp*
Measurement of Flexural Stiffness of Hummingbirds' Feathers and Its Aerodynamic Effect in Hovering
Hovering hummingbirds generate aerodynamic lift during both downstroke and upstroke by rotating their wings along with spanwise direction. Since their wings are composed of radially-spread multiple feathers, passive flexural deformation of each feather is expected to contribute the rotational twist of the wings. Flexural stiffness of the feathers and its distribution in the hummingbird wing, however, are still largely unknown. In this study, we directly measured the flexural stiffness of feather shafts of a museum specimen of hummingbirds as well as several other species of small birds by cantilever bending tests for multiple locations aiming to quantify the features of distributed flexural stiffness of the hummingbirds. Moreover, in order to investigate its effect on lift generation in hovering, we created wing models from polyimide films and UV-laser-cut CFRP (carbon fiber reinforced plastic) artificial feather shafts mimicking the measured flexural stiffness. The bending tests revealed that the flexural stiffness exponentially increased with the distance from the feather tip. It was also found that the inner feathers were notably less stiff than the other leading feathers in hummingbirds, unlike other small birds. By comparing the wing model for hummingbirds with that for other small birds using an electric flapping mechanism mimicking hummingbird hovering, we found that increased flexibility of the inner feathers induced further rotational torsion at distal region, resulting in increase in lift and decrease in power consumption. This suggests that stiffness of the hummingbird feathers have evolved to adapt for their unique hovering flight.

102-2 TANNER, RL*; GLEASON, LU; DOWD, WW; Washington State Univ., California State Univ. Sacramento; *richelle.tanner@wsu.edu*
Transcriptomic and proteomic analyses of inter-individual variation among intertidal mussels
Microclimate differences within heterogeneous habitats, such as the rocky intertidal zone, have the potential to shape population-level responses to changing environmental conditions. However, the relationship between temporal and spatial variation in microclimate and inter-individual physiological variation remains poorly resolved. Here, we use a population of rocky intertidal zone mussels, *Mytilus californianus*, to investigate the interaction between microclimate and biochemical/physiological responses. We have previously shown that stressful conditions promote high inter-individual variation in antioxidant capacity; conversely, relatively benign conditions correspond with higher inter-individual variation in oxidative damage. This mismatch between "defense" and "damage" may have roots within strategies at the biochemical network level and result from maintaining a window of sublethal damage with variable defense. For this study mussels originated from either wave-protected or wave-exposed sites, after a common garden, and after outplant to either low or high intertidal field sites. From extracted gill tissue, the de novo transcriptome was mapped using Bowtie, annotated with BLAST2GO, and assembled in Trinity. Proteins were identified based on the transcriptome and quantified using Scaffold. Differential variability was calculated using the median absolute deviation, and investigated for potential dependency on differential expression results. Resulting correlation networks for both differential expression and variability were analyzed in Cytoscape. Using these transcriptomic and proteomic approaches, we can explore whether highly variable networks, or key regulators thereof, are possible avenues of selection under stressful environmental conditions.

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Social change for climate change: communication tactics from the National Network for Ocean and Climate Change Interpretation

Communicating climate change research to the public, or even researchers outside of the field, can be tough. Linguistic and framing research has shown that communication differs in comprehension, "stickiness" (or how well the message is remembered), and transferability (or how well a listener can relay a lesson to others). The National Network for Ocean and Climate Change Interpretation has developed a series of tested metaphors and communication tactics based on social science research that rely on shared societal values. We present a tested metaphor to explain the mechanism of climate change called the "heat trapping blanket" and show how it can be used as a component of a larger climate communication. Through simple metaphors like the "heat trapping blanket", climate change research is threaded through shared societal values of protection and responsible management, culminating in a call to action for the audience. Much of the presented material here is covered in greater depth in our offered workshops; more information is available at www.climateinterpreter.org. Scientists have a responsibility to participate in community conversations about climate change - here we present an effective, formulaic method for framing climate change presentations, whether it be to the public or fellow scientists.

59-2 TAO, L*; OZARKAR, S; BHANDAWAT, V; Duke University;
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Mechanisms underlying attraction to odor in walking Drosophila

Thorough characterization of the behavioral strategy by which animals search an environment and how this pattern is affected by sensory stimuli is an important step for understanding the neural processes that give rise to these behaviors. The *Drosophila* olfactory system is an excellent model organism to study these strategies because of its relative simplicity, the availability of genetic tools and because odors have a marked effect on its locomotion. In this study, we uncover the statistical nature of odor modulation of locomotion and propose a simple model that captures much of the variability in attraction. We created an 8 cm diameter circular arena with a 2.5 cm concentric circular region illuminated with red light. We expressed the red-light activated channelrhodopsin, Chrimson, under the control of *Orco-Gal4* (*Orco-Gal4; UAS-Chrimson*) to activate a large fraction of all ORN classes in the presence of red light. These flies were previously reported to exhibit strong attraction to red light. We show that fly locomotion can be modeled as sequences of sharp turns, directed runs, and stops. We found that there are two mechanisms underlying attraction to odors: First, activation of ORNs changes the distribution of stops, runs and turns. These kinematic changes explain a small, but significant fraction of the attraction to odor. Second, and a far more important mechanism, is an increase in the density of sharp turns and tight control of turn direction around the light border. We then created a simple generative model of locomotion. The synthetic flies we generate using our model not only replicate the level of attraction, but also approximate the temporal progression of attraction in the presence of odor and the variability in attraction. These results have important implications for neural control of odor-modulation of locomotion.

133-7 TAPPER, SJ*; NOCERA, J; TATTERSALL, G; BURNESS, G; Trent University, University of New Brunswick, Brock University; *simontapper@trentu.ca*

Body temperature regulation during the acute phase response in zebra finches

In birds, acute stress generally causes an increase in core body temperature. During this stress-induced hyperthermia, blood flow is redirected from peripheral tissues such as the bill and legs, which then causes a decrease in skin temperature. While this mechanism is understood, less is known about how peripheral tissues are involved in body temperature regulation during illness (i.e. the acute phase response). To determine if immune-challenged birds direct body heat using the same mechanism as birds experiencing stress, we injected zebra finches (*Taeniopygia guttata*) with a bacterial endotoxin and monitored skin temperature and core temperature using infrared thermography and thermal PIT tags respectively. Results concerning the degree and timing of changes in skin temperature relative to core temperature will be discussed.

83-6 TAPPER, S; NOCERA, JJ; BURNESS, G*; Trent University, University of New Brunswick; *garyburness@trentu.ca*

Is the energy expenditure of breeding birds limited by the risk of overheating?

Breeding birds may spend many weeks feeding their nestlings, resulting in a sustained increase in parental energy expenditure. But what sets the limit on how hard an individual works, especially if there are potential fitness benefits of raising more nestlings? The heat dissipation limit theory proposes that maximum sustained rates of energy expenditure are constrained by an individual's capacity to dissipate metabolic heat (Speakman and Krol 2010). To test this, we studied breeding tree swallows, an aerial insectivore in which both parents forage for up to 15 hours per day. We predicted that if an individual's capacity for sustained energy expenditure were limited by the risk of overheating, then individuals with increased capacity to dissipate heat would have higher nestling feeding rates. To increase heat dissipation capacity we experimentally increased the size of the brood patch in breeding females, by trimming the overlying feathers. Males do not have a brood patch and were un-manipulated. We also implanted temperature-sensitive passive integrated transponder (PIT) tags, which allowed us to monitor body temperature and feeding rates remotely. As predicted, females with experimentally enlarged brood patches had higher nest visitation rates than both un-manipulated females and males. These data support the hypothesis that risk of overheating limits parental provisioning performance in this species.

P3-177 TASSIA, MG*; HALANYCH, KM; Auburn University, Auburn, AL; *mgt0007@auburn.edu*

Evolution of pattern-recognition receptor pathways and the identification of novel domain architectures in Deuterostomia

Immunity fundamentally relies on the host's capacity to distinguish unwanted, potentially pathogenic microbes from a slurry of endogenous biological materials and other functionally inert molecules saturating the environment. To combat this colossal task, animals utilize various pattern-recognition receptors (PRRs) to identify and initiate immune responses against individual groups of pathogens. The patterns PRRs recognize, such as lipopolysaccharide (found in Gram-positive bacteria) or dsRNA (found in viruses), are often essential to the structure/biology of the potentially pathogenic agent on/in which they are found, and thus remain consistent/present over evolutionary time. Moreover, individual PRR proteins often only recognize a single classification of molecular pattern, like Gram-positive cell wall components or viral nucleotide polymers, suggesting an increase in the number of PRRs encoded in a single genome may represent increased immune capacity against a larger breadth of pathogens. In this study, we investigate the molecular conservation of the Nod-like receptors, Rig-1-like receptors, and Toll-like receptor PRR pathways among deuterostomes - a clade encompassing Echinodermata (e.g., sea stars, urchins, and sea cucumbers), Hemichordata (e.g., acorn worms and pterobranchs), and Chordata (e.g., sea squirts, lancelets, and vertebrates). In addition to findings on the ancestral repertoire of these pathways in the context of Deuterostomia and its composite clades, we will discuss novel domain architectures in close association with these core PRR pathways, and their potential role in immunity.

38-2 TAVERNE, M*; FABRE, AC; DUTEL, H; TADIC, Z; FAGAN, M; HERREL, A; Muséum National d'Histoire Naturelle, Paris, Natural History Museum, London, School of Engineering, Hull, Department of Biology, Zagreb, School of Engineering, Hull; *maxime.taverne@mnhn.fr*

Phenotypic diversification in insular populations of Podarcis lizards: how do diet and bite force drive variation in skull morphology?

Changes in the environment drive diversification in morphology as survival is intricately related to the constraints associated with the new habitats. Islands are strong selective environments since they provide only a limited amount and diversity of resources, thus increasing the intensity of competition compared to mainland populations. Previous studies have highlighted that changes in diet are associated with changes in skull geometry and bite force in insular lizards. However, little is known about the functional consequences of skull shape differences in association with access to food resources on islands. The present study explores whether insular lizards have converged on similar morphologies in relation to diet and variation in bite force. The heads of 140 individuals across two closely related species of *Podarcis* lizards from 16 islands across the Adriatic were CT-scanned, 3D surfaces of both skull and mandible were extracted and compared using 3D geometric morphometrics. Maximal bite force was measured for each individual and food items were identified after stomach flushing. We tested whether changes in diet were correlated with bite force, and whether changes in bite force were associated with variation in skull shape. We predict that higher bite forces will allow the inclusion of more plant matter and/or harder prey in the diet. Moreover, we predict changes in skull shape associated with higher bite forces. The present study will provide new insights on how insular environments select for different phenotypes and whether these differences are related to diet and biting performance.

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Maximal Load Carrying Performance of Leaf-cutter Ants

Leaf-cutter ants play an important role in maintaining the biodiversity of neotropical forests by cutting and transporting leaf fragments from the canopy to their underground colonies. After cutting the leaves, ants lift the fragments overhead and carry them for long distances over well-established foraging trails. Previous studies have demonstrated that larger ants carry heavier leaves and that larger loads decrease walking speed. However, little is known about the maximum limits of load carrying ability in leaf-cutter ants, particularly in relation to the size of the self-selected fragments they carry and the excess power reserves they maintain to overcome obstacles. By incrementally adding weights to leaf fragments carried by foraging ants, we examined the relationship between body mass and maximum lifting power. As the ants reached maximum load carrying ability, their stepping pattern changed: walking speed slowed, leg stance widened, and staggering increased. Maximum load carrying ability scaled isometrically with body size and leaf-cutter ants were able to carry 7.8 times their body weight. However, larger ants chose to carry leaf fragments that represented a lower proportion of their body mass compared to smaller ants. This suggests that larger ants have the capacity to carry heavier leaves than they normally select and that the mechanism by which leaf-cutter ants choose leaf fragments to transport is not optimized for maximum foraging efficiency.

89-1 TAYLOR, HA*; PARK, NR; KAVAZIS, AN; HOOD, WR; Auburn University; *hat0008@auburn.edu*

Variation in Mitochondrial Complex Activity, Oxidative Stress, and the Unfolded Protein Response in the Brain of Mice with Region and Parity

Reproduction is associated with a significant increase in energetic demand, particularly among small female mammals. When these demands are particularly high, or the animal is under stress, the cost of reproduction can reduce future reproductive performance and longevity. An increase in reactive oxygen species (ROS) levels has been proposed to underlie this relationship. While empirical tests of this theory have been equivocal, relatively few studies have evaluated change within the brain. Prolonged exposure to excessive levels of ROS has been shown to impair cognitive ability. Further, correlations have also been found between the number of reproductive bouts a female has and the risk of developing neurological disorders. These correlations suggest there is a link between relative parity and brain damage over a lifetime. With this investigation, we compare mitochondrial complex activity, oxidative damage, antioxidants and the linked, unfolded protein response in the forebrain, midbrain, and the cerebellum of 3 groups of the of ICR lab mice. These age-matched mice include 1) a group of non-reproductive mice, 2) a group of mice that had 1 reproductive event, and 3) a group of mice that had 4 reproductive events. Preliminary data suggests that antioxidant levels vary between forebrain, midbrain, and the cerebellum, but damage and antioxidants did not vary with parity. The impact of treatment on mitochondrial function via complex activity and the unfolded protein response will be discussed.

P1-60 TAYLOR, BK*; CORBIN, S; The University of North Carolina at Chapel Hill, The University of West Florida; *brian.taylor@unc.edu*

Bioinspired magnetoreception and navigation in non-orthogonal environments

Diverse taxa use Earth's magnetic field in conjunction with other sensory modalities to accomplish navigation tasks ranging from local homing to long-distance migration across continents and ocean basins. However, despite extensive research, how animals use Earth's magnetic field in a strategy to successfully navigate is an active area of investigation. Concurrently, Earth's magnetic field offers a signal that engineered systems can leverage for navigation in environments where man-made systems such as GPS are unavailable or unreliable. Building on previous work, this study uses a proxy for Earth's magnetic field, and implements a behavioral strategy inspired by migratory animal behavior that uses combinations of magnetic field properties as rare or unique signatures to mark specific locations. In particular, this work allows constant lines of proxy inclination and intensity to be either rectilinear or curvilinear, and rotated relative to one another so that they are either perpendicular or non-uniformly non-perpendicular. The strategy is tested under a variety of environmental parameters (e.g., rotation angle, degree of curvilinearity), and strategy parameters (e.g., measurement frequency, measurement noise). The results provide support for existing notions of some animals using combinations of magnetic properties as navigational markers, and provides insights into features and constraints that may enable navigational success or failure. The findings also offer insight into how autonomous engineered platforms might be designed to leverage the magnetic field as a navigational resource.

93-7 TAYLOR, J.R.A.; University of California, San Diego; *j3taylor@ucsd.edu*

Biomechanics of crab skeletons on land

As crabs made the evolutionary transition from aquatic to terrestrial environments, they faced a shift in the mechanical challenges imposed on their skeletal support systems. Exacerbating the challenges of transitioning to land is the need to accommodate two fundamentally different modes of skeletal support- rigid and hydrostatic. As the largest arthropods to inhabit both environments and use two distinct skeletons, crabs are an interesting system to examine biomechanical adaptations in skeletal support systems. I hypothesized that terrestrial crabs would have modified morphology to enhance mechanical stiffness in both the rigid and hydrostatic phases, which would provide more support against greater gravitational loading. Using the terrestrial blackback land crab, *Gecarcinus lateralis*, and the aquatic blue crab, *Callinectes sapidus*, I measured and compared body mass, merus morphology (dimensions, cuticle thickness, and *I*) and mechanics (*EI*, *E*, critical stress, and hydrostatic pressure) of rigid and hydrostatic stage crabs encompassing a range of sizes (*C. sapidus*: 1.5-133 g, N ≤ 24; *G. lateralis*: 22-70 g, N ≤ 15). Results revealed that rigid *G. lateralis* has similar merus morphology [merus length/merus diameter (L/D) and cuticle thickness/merus diameter (T/D)] and mechanics (*EI*, critical stress) to *C. sapidus*. In contrast, hydrostatic land crabs differ from aquatic crabs by having different morphology (thinner cuticle) and mechanics (greater internal pressures). These results suggest that the rigid crab body plan is inherently overbuilt and sufficient to deal with the greater gravitational loading that occurs on land, while mechanical adaptations are important for hydrostatically supported crabs. The hydrostatic skeleton of crabs appears to experience greater challenges with gravity and, as a result, may impose greater constraints to crab growth on land.

68-5 TAYLOR-BURT, KR*; BIEWENER, AA; Harvard University; *karitaylorburt@fas.harvard.edu*

Is the lateral gastrocnemius tuned for a mallard duck's preferred cycle frequency?

Mallard ducks use different strategies for increasing speed when moving over land *vs.* in the water. Notably, they increase leg cycle frequency in order to go faster on land but prefer to use a constant cycle frequency (2.6 Hz) across their full range of speeds during surface swimming. Stride frequency and stride length interact to determine where leg muscles act on the length-tension and force-velocity curves. The lateral gastrocnemius (LG) is a large ankle extensor in ducks that is important for powering surface swimming. We wanted to test whether the LG was tuned to operate at 2.6 Hz; specifically, does it produce maximal work or power at 2.6 Hz? We used the work loop technique to examine *in situ* LG work and power production at 3 frequencies: 2.6 Hz, the *in vivo* condition, as well as a lower (1 Hz) and higher (4 Hz) frequency. We performed muscle work loops at submaximal stimulation and used a constant length excursion, stimulation duty factor, and phase at stimulation onset that mimicked literature values for *in vivo* muscle excursion and activation patterns. For all ducks we examined (n=6), work decreased with increasing frequency because the muscle had time to develop higher forces at lower frequencies. In 3 ducks, power increased with frequency, and in the other 3, power was higher at 2.6 Hz than at lower or higher frequencies, suggesting that 2.6 Hz might permit maximal LG power production for some animals. Alternatively, a 2.6 Hz cycle frequency may represent a compromise between work and power production, at least for the LG. Additional studies are needed to examine the effect of cycle frequency on work and power production in other mallard leg muscles and to determine whether 2.6 Hz has a hydrodynamic significance.

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Rapid Cold Hardening Provides Sublethal Benefits in an Antarctic Extremophilic Insect

The Antarctic midge, *Belgica antarctica*, is the world's southernmost insect and the only insect endemic to Antarctica. Larvae of this species are highly tolerant of a variety of environmental stressors and can survive freezing down to -20°C in the laboratory. However, field microhabitat temperatures rarely approach -10°C, indicating that most freezing events are sublethal. To cope with sudden drops in temperature, the midge is capable of rapid cold hardening (RCH), a rapid acclimation response that enhances cold tolerance. Previous work has demonstrated that RCH protects against lethal freezing at extreme temperatures, but the extent to which RCH provides benefits during sublethal freezing is unknown. Here, we test the hypothesis that RCH promotes faster recovery, preserves energy balance, and protects against protein and tissue damage following sublethal freezing. Larvae were either directly frozen at -9°C for 24 h, or given 2 h of RCH at -5°C prior to 24 h at -9°C. Larvae exposed to RCH before freezing recovered more quickly and resumed normal movement well before those that were directly frozen. Furthermore, larvae that underwent RCH had higher metabolic rates 2 h after cold stress. Thus, RCH preserves metabolic function and allows larvae to resume normal activity more quickly following a bout of freezing. In ongoing analyses, we are testing the ability of RCH to maintain tissue integrity, conserve energy, and modulate stress-protein expression. Taken together, this work will indicate the extent to which RCH preserves function at the molecular, cellular, and organismal levels following ecologically relevant freezing events.

101-3 TEETS, NM; DIAS, V; SCHETELIG, MF; HANDLER, AM; HAHN, DA*; University of Kentucky, International Atomic Energy Agency, Justus-Leibeg University, United States Department of Agriculture, Univesity of Florida; *dahahn@ufl.edu*
Making macho males by transgenic overexpression of a mitochondrial antioxidant enzyme
Many environmental stressors generate reactive oxygen species and a substantial body of work indicates that key life history traits from mating performance and sexual selection to longevity are mediated by oxidative stress. Here, we test the hypothesis that transgenic overexpression of a key antioxidant enzyme reduces oxidative damage and enhances mating performance in the context of oxidative stress. We have previously shown that females choose males with higher levels of antioxidant enzyme activity when exposed to oxidative stress prior to mating in the Caribbean fruit fly, *Anastrepha suspensa*, a species with a highly demanding lek mating system. Here we generated seven transgenic Caribbean fruit fly lines that overexpress mitochondrial superoxide dismutase (MnSOD), a key antioxidant enzyme that metabolizes damaging superoxide radicals. After exposure to severe oxidative stress, two of the lines with intermediate MnSOD overexpression showed enhanced mating performance relative to sterilized wild type males. In these two lines, improvements in mating performance and climbing corresponded with a reduction in oxidative damage to lipids, indicating that MnSOD overexpression protects flies from oxidative stress at the cellular level. Taken together, our results show a clear link between oxidative stress, antioxidant capacity and male performance, and our work shows promise for applications using transgenic approaches to enhance the efficacy of insects released as components of area-wide pest management strategies such as the sterile insect technique.

99-7 TENGLER, M*; BRYAN, A; REICHMUTH, C; THOMETZ, NM; University of San Francisco, Alaska Department of Fish and Game, University of California, Santa Cruz; *mtengler@usfca.edu*
Physiological Development of Locomotor Muscles Influence Diving Capacities in Free-Ranging Bearded Seals
Seals must store and efficiently use oxygen while diving and foraging at depth. Like all mammals, they store oxygen in their lungs, blood, and muscle, but the physiological properties of skeletal muscles play a disproportionately large role in defining diving capacities. Further, pups are not born with the same physiological abilities as adults, with muscle oxygen stores typically beginning to develop at the onset of independent foraging. Bearded seals (*Erignathus barbatus*) are large ice-dependent Arctic seals. They dive to the seafloor to search for and consume benthic fish and invertebrates, and use sea ice as a platform to rest between foraging bouts. In this study, we examined the physiological development of bearded seal locomotor muscle (longissumus dorsi). Samples were obtained from subsistence harvested bearded seals (n = 37) of different ages collected at Point Hope, Alaska. All muscle samples were analyzed for both myoglobin content and non-bicarbonate buffering capacity. We found clear and progressive ontogenetic trends in skeletal muscle physiology, which indicate that young bearded seals are at a physiological disadvantage in diving and foraging ability when compared to adults. These data provide insight into potentially sensitive life-stages, during which individuals are likely constrained in their behavior. Ultimately, defining age-specific diving capacities and physiological limitations can inform understanding of bearded seal habitat use and aid in predicting behavioral responses to environmental change.

P3-18 TEWKSBURY, CD*; WILKINSON, K; GERSTNER, CFE; GERSTNER, GE; University of Michigan, Ann Arbor, University of Michigan, Ann Arbor , A2 Hosting, Ann Arbor, MI; *geger@umich.edu*
Masticatory Jaw Movements in Pigs, Where and When Does Variation Occur? Insights with Functional Data Analysis
Mastication is a mammalian motor behavior used to reduce and mix food with saliva before swallowing. During mastication, the jaw moves rhythmically through openings and closings, tracing a three-dimensional path. Variability in these movements results primarily from variation in food properties; however, feedforward and feedback mechanisms work to reduce the variation. Most mastication studies are based upon measurements taken at a finite set of heuristic time points in the continuous movements. This omits considerable information content in the movements. We hypothesize that critical food- and individual-specific variation occurs during times that are not typically analyzed. We employ functional data analysis (FDA) to test this hypothesis. FDA transforms complete movements into basis functions, which serve as observations for statistical analyses. We used masticatory jaw movements from four omnivorous pigs fed three foods, viz., almonds, carrots, and apples. Time series representing jaw movements were provided by Dr. Susan Williams' lab as part of a collaborative project. Functional analysis of variance (fANOVA) was used to test main effects of individual pig and food and two-way interactions. Results demonstrate that significant differences exist in time points that are rarely if ever analyzed with traditional methods. Thus, FDA is a useful approach for understanding the dynamics of complex, continuous movements in functional morphological and motor control studies.

P2-18 TEWS, V/H*; BARNETT, A/A; DeSales University, DeSales Univeristy; *veronikatews@yahoo.com*
Interrogating the Evolution of Epidermal Growth Factor (EGF) Pathway Ligands in Insects
The EGF pathway is a conserved and ubiquitously used cell signaling cascade in animal development. In the highly studied insect *Drosophila melanogaster*, four ligands (Vein, Gurken, Spitz and Keren) are used to activate the pathway, and the protein Argos represses activation of the EGF pathway by binding to the EGF receptor. An arthropod-centered phylogenetic analysis showed that the genes encoding the ligands Vein and Argos were present in the last common ancestor of all arthropods. However, this analysis showed the genes encoding Gurken evolved in the last common ancestor of the Diptera, the clade including flies. Our analysis also provides evidence that spitz and Keren are the result of a gene duplication event in the Tephritid flies. In an attempt to determine the ancestral role of the *spitz/Keren* gene in the context of insect development, we used RNA interference targeting the orthologues of the genes in two separate lineages, Orthoptera and Hemiptera. These lineages are represented by the cricket *Gryllus bimaculatus* and the milkweed bug *Oncopeltus fasciatus* respectively.

10-1 THANDIACKAL, R*; MELO, K; PAEZ, L; KANO, T; ISHIGURO, A; IJSPEERT, AJ; Harvard University, École Polytechnique Fédérale de Lausanne, Tohoku University; *rthandiackal@gmail.com*

Undulatory swimming control with local exteroceptive sensory feedback

Control of undulatory swimming is due to the interplay of central and peripheral mechanisms. It has been observed that centrally distributed neural networks along the spinal cord, so-called central pattern generators (CPGs), contribute to spontaneous rhythm generation in a variety of animal species (e.g. lampreys, leeches or salamanders). On the other hand, local feedback loops exist that are able to modulate and alter the activation patterns along the body. However, much less is known about these feedback mechanisms and because it has proved difficult to analyze their contribution isolated from the central nervous system, corresponding models have become valuable tools for investigations. Some models have described CPGs together with local proprioceptive feedback loops involving stretch receptors and attempted to quantify their respective contributions. In our recent study we present a new model that incorporates exteroceptive sensing by means of local pressure/force measurements. The model is based on phase oscillators with local force feedback and simple muscle models. We used both simulation and a robot to test our model and made two major findings. (1) Travelling waves of undulation can emerge spontaneously in the absence of any central coupling along the body and feedback loops can take over the role of synchronizing the oscillatory centers. (2) In the absence of CPGs, (centrally coupled) purely sensory-driven oscillations can generate coherent traveling waves along the body. Our results highlight the importance of body-environment interaction for pattern generation in undulatory swimming and suggest that incorporation of local force and/or pressure sensing and feedback provides redundancy and robustness for undulatory swimming control.

29-5 THAWLEY, CJ*; HALL, JM; KOLBE, JJ; University of Rhode Island, Auburn University; *cthawley@uri.edu*

Turn Up the Lights In Here: Impacts of Artificial Light at Night on Anoles

As anthropogenic global change increases, one aspect of urbanization that affects many species is artificial light at night (ALAN). ALAN is known to have serious implications for nocturnal taxa, but we do not have a good understanding of how it affects many diurnal animals, including reptiles. While anole lizards are considered to be strongly diurnal and adapted to specific photic environments, many anole species thrive in human-altered habitats where ALAN is prevalent. Previous research exposing brown anoles (Anolis sagrei) to ALAN in the lab shows that ALAN can induce earlier reproduction and increase growth and reproductive output. Research in the field shows that exposure to ALAN can increase wariness and decrease endurance. To illuminate the impacts of ALAN in a real-world scenario, we conducted a field experiment introducing a common form of ALAN, landscape lighting, into a previously unlighted habitat within an urban matrix. Over a two-month period, we monitored sleeping perches, survival, growth, body condition, and physiology of brown anoles and crested anoles (Anolis cristatellus). We found that anoles did not avoid artificially lighted areas and did experience higher light levels at sleeping perches in ALAN treatments. Anoles sleeping in artificially lighted locations had lower blood glucose. ALAN exposure also reduced follicle size in females and altered egg mass, suggesting impacts on energy availability. As urban and human-developed areas continue to grow, ALAN will increasingly affect both urban exploiters and urban-tolerant organisms. Considering the ecological impacts of ALAN as an evolutionarily novel disturbance is important to future studies of urban ecology and conservation.

P3-114 THOMAS, PA*; LOPEZ-LEGENTIL, S; WILBUR, AE; KINSEY, ST; University of North Carolina, Wilmington; *pat3805@uncw.edu*

Effects of Air Exposure on Markers of Oxidative Damage in an Invasive Tunicate (Styela plicata) and a Native Shellfish (Crassostrea virginica)

The Eastern oyster, *Crassostrea virginica*, co-occurs with the invasive tunicate, *Styela plicata*, and the latter species is particularly prevalent in oyster hatcheries, where it is a potential competitor of oysters for food and space. We evaluated the role of air exposure on oxidative damage in both species to help understand environmental tolerances. 70 individual tunicates and 70 individual oysters were collected from the docks of UNCW's Center for Marine Science. Tunicates were of various sizes (ranging from 19-80 mm) while oysters were of similar sizes (ranging from 28-57 mm, ages 6 to 9 months). 10 individuals from each species were randomly placed in one of the following 7 groups: control (continuous water immersion), 6, 12, or 24-h air exposure, or 6, 12, or 24-h air exposure followed by 6 h of water immersion. Tissues from both organisms were examined for oxidative damage using immunoblotting procedures for ubiquitin (protein degradation), protein carbonylation (protein oxidative damage), and 4-HNE (lipid oxidative damage). Tunicates had greater increases in oxidative damage markers than oysters, suggesting that air exposure may lead to increased physiological stress in this species. There was also evidence of a negative correlation between tunicate length and each marker of oxidative damage, suggesting that size of the individual plays a role in the extent of the stress induced by air exposure. This interaction could mean that frequent air exposures will prevent larval and juvenile *S. plicata* recruitment. This research has implications for the use of air exposure as a method to reduce invasive tunicate densities on oyster cages without significantly dampening oyster growth and viability.

29-6 THOMAS, S*; PURRENHAGE, JL; FOSTER, A; LOUCEK, J; ROEDER, A; BRANCH, TL; MOORE, F BG; NIEWIAROWSKI, P H; The University of Akron, University of New Hampshire; *scott06thomas@gmail.com*

Spotted salamander (Ambystoma maculatum) breeding population structure and dynamics across 20 years at a northeastern Ohio pond

Long-term demographic data are essential tools for interpreting and predicting the population structure and dynamics of long-lived species. Furthermore, an understanding of the ecological factors shaping such data allows for insights to be shared across populations in divergent contexts or for which information is limited. Here, we present findings from a 20 year ongoing mark-recapture study of spotted salamanders (*Ambystoma maculatum*) breeding at a drift-fenced pond in northeastern Ohio, USA. This breeding population has fluctuated over an order of magnitude across the study period, ranging from less than 200 to greater than 2000 individuals. Consistent with many other amphibian populations, we also found that sex ratios here skew strongly male, and overall population dynamics are largely male-driven while female numbers have remained relatively stable. For individuals, we found the capacity for extensive iteroparity and longevity, but a majority of this population participates in only a single breeding bout. Additionally, we investigate the role of various ecological factors in shaping the observed dynamics, focusing on sources of variation in larval growth and mortality that vary considerably across breeding ponds. Finally, we compare our findings with those from other long-term studies of this unusually well-studied genus in order to identify general patterns and suggest areas for future inquiry.

98-3 THOMETZ, NM*; ROSEN, D; REICHMUTH, C; Univ. of San Francisco, Univ. of British Columbia , Univ. of California, Santa Cruz ; *nthometz@usfca.edu*

Seasonal Energetics of Ice-Dependent Arctic Seals Reveal the Metabolic Consequences of Different Molting Strategies

Ice-dependent Arctic seals, including bearded (*Erignathus barbatus*), ringed (*Pusa hispida*), and spotted (*Phoca largha*) seals, are uniquely affected by sea ice loss. These species use sea ice as a substrate for various critical functions, including rest, giving birth, nursing, predator avoidance, and foraging. They also rely on sea ice during the annual molt, when they shed several layers of epidermis and fur and grow a new coat. To facilitate this process, seals haul out for extended periods, increase blood flow to the skin, and maintain elevated skin temperatures. Molting is assumed to have a significant metabolic cost, which would increase if appropriate haul-out substrate were unavailable; however, molting costs have only been quantified for a few species. Working with trained seals, we tracked changes in coat condition and seasonal energetic demands to identify key periods when the loss of sea ice may have the greatest impact. We documented the timing, progression, and duration of the visible molt for bearded (n=2), ringed (n=3), and spotted (n=4) seals. In addition, we used open-flow respirometry to track fine-scale changes in the resting metabolic rate (RMR) of six seals for a minimum of one year. We observed clear patterns in seasonal costs that related to the distinct molting strategies of each species. For species that molted over a short interval (spotted: 36±4.6 days, ringed: 29±2.5 days), RMR increased on average 26-47% across the molting period. In contrast, molting over a longer interval (bearded: 107±14.8 days) appeared to limit the cost of molting as indicated by a stable annual RMR. This study highlights the relationship between molting strategy and seasonal energetic requirements and provides quantitative data that can be used to assess species-specific vulnerabilities to changing conditions.

P1-85 THOMPSON, SJ*; POWERS, DR; George Fox University; *sthompson16@georgefox.edu*

Is Daytime Mass Management and Pre-Roost Hyperphagia Common in Hummingbirds?

Several studies assume hummingbirds fill their crop prior to roosting, and have included crop filling in nighttime metabolism protocols. To test the validity of this assumption, we examined daytime mass management in both males and females of three SE Arizona hummingbird species that differ in size and ecological role: the black-chinned hummingbird (*Archilochus Alexandria*, 3.0g; opportunistic forager), the Rivoli's hummingbird (*Eugenes fulgens*, 7.5g; trap-liner), and blue-throated hummingbird (*Lampornis clemenciae*, 8.0g; territorialist). Male Rivoli's and black chinned hummingbirds maintained mass throughout the day, but appeared to crop load prior to roosting. Blue-throated hummingbirds maintained mass but did not crop load, and fed infrequently during the last 30 minutes of activity, possibly due to unlimited access to resources. Female black-chinned hummingbirds exhibited high variation in mass and no crop-loading even though they were numerically dominant at the feeders during the last 30 minutes of activity. In contrast, female blue-throated and Rivoli's hummingbirds had higher activity in the beginning and end of the day, but were infrequent visitors to feeders mid-day when temperature was high. These data suggest that daytime mass management and pre-roost crop loading is likely influenced by social interaction and to some degree thermal tolerance. Additionally, since this study was conducted during the breeding season, females were likely influenced by egg production, and all phases of nest construction and attendance.

72-5 THOMPSON, DB; University of Nevada, Las Vegas; *daniel.thompson@unlv.edu*

The Ontogeny of Static Allometry is Not So Simple for Grasshoppers: Genetic Variation for Nutrient Sensitive Plasticity is Masked by Size-Dependent Compensatory Growth

Grasshoppers develop larger head width and shorter leg length, relative to body size, when fed low nutrient, silica rich grasses compared to sibs fed a diet of high nutrient grasses. To elucidate how underlying genetic variation and plasticity of growth generate static allometry in *Melanoplus sanguinipes* (Orthoptera; Acrididae), I measured head and leg size of three nymphal instars and adults raised on either a low or high nutrient diet within a half-sib quantitative genetic experiment. A doubly-multivariate MANOVA of head growth, leg growth, and growth period per instar was used to analyze how these variables and additive genetic variation for plasticity (G x E interaction) contribute to scaling of functional allometry (trait x instar x G x E). Genetic variation for diet-induced plasticity of head and leg size varied through ontogeny, as did genetic variation for plasticity of growth in 3rd and 4th instar nymphs. Despite extensive genetic variation in plasticity of head width and leg length in the 4th instar, the static allometry between head and leg was stable within each diet because the patterns of G x E were concordant for head width, leg length and their coordinated growth. However, genetic variation for 4th instar morphological plasticity was suppressed in adults by negatively size-dependent compensatory growth in the last period of ontogeny. Bivariate reaction norms of adult head and leg size were parallel with diet specific scaling but no G x E. Thus, the hemimetabolous ontogeny of seemingly simple allometry between functional body parts comprised qualitatively different patterns of nutrient sensitive growth rates and periods and compensatory or targeted growth, all relevant to understanding development and evolution.

P1-294 THOMPSON, MC*; FENG, H; WUCHTY, S; WILSON, ACC; University of Miami, Coral Gables, FL; *mct30@miami.edu*

Evidence of Plant-encoded miRNAs in Green Peach Aphid (Myzus persicae) Gut

The aphid/*Buchnera* symbiosis was the first insect nutritional endosymbiosis for which the genome of both the insect and its symbiont were known. In this model, *Buchnera* are housed intracellularly in bacteriocytes within bacteriomes where they work to provide essential amino acids to the host aphid. Recently, we worked to characterize miRNAs that are implicated in regulation of the symbiosis in the green peach aphid, *Myzus persicae*. To do this we generated small RNA-seq datasets from aphid gut and bacteriome tissue. Remarkably, we found that 45% of reads in gut samples failed to map to the aphid and/or *Buchnera* genomes. In contrast, only 5% of reads from bacteriome samples failed to map to the aphid and/or *Buchnera* genomes. Here we report our interrogation of the 45% of small RNA-seq reads in gut samples that failed to map to the insect and/or symbiont genome. We found that viruses and possible secondary symbionts were not likely sources of these reads. Rather, 67% of these unknown reads mapped to the genome of the host plant, *Brassica oleracea*. *B. oleracea* reads represented 31% of all reads from gut tissue samples. A subset of these *B. oleracea*-mapped small RNAs were annotated as plant miRNAs with putative targets in the both the *B. oleracea* and *M. persicae* genomes. Our results provide foundational evidence for the regulation of aphid gene expression by plant-encoded miRNAs. This knowledge both advances understanding of cross-kingdom gene regulation in plants and insects, and expands understanding of the regulatory interactions surrounding aphid feeding.

123-1 THOMPSON, WA*; SUBBIAH, S; CLEARY, R; LASEE, S; KARNJANAPIBOONWONG, A; ANDERSON, TA; University of Georgia, Texas Tech University; *willthompson131@gmail.com*

Chronic Toxicity of Perfluoroheptanoic acid (PFHpA) and Perfluorooctanoic acid (PFOA) to Northern Bobwhite

This project's primary objective was to characterize any adverse impacts of PFAA to birds, with growth, development, and survival as the primary endpoints. PFAAs are a class of persistent, anthropogenic pollutants used in a wide variety of products for their non-reactivity, including in aqueous firefighting foam (AFFF). Secondary endpoints included examining how much accumulation of the target chemical occurs in liver tissue and how the body burden of PFOA and PFHpA, the two target PFAAs of this study, are altered by egg deposition. Furthermore, this project attempted to assess how much of the target chemical was present in egg yolk and how much juvenile quail retain after one month of growth. Chronic toxicity of the two target compounds was tested using Northern Bobwhite as the model species. Adult birds were exposed to drinking water containing 20 ng/mL, 1 ng/mL, and 0.1 ng/mL of the target chemical over the course of study (90 days). Residue analysis was conducted on adult and juvenile liver tissue as well as on eggs. Neither PFHpA or PFOA reduced hatching success, reproduction, or adult or juvenile Northern bobwhite survival at 1.860 or 1.745 µg/kg/day, respectively. However, it did appear that chronic ingestion of PFOA (1.745 µg PFOA/kg/day) may significantly increase the weight of hatchling birds after one week, an effect observed in other vertebrates. Furthermore, residue analysis confirmed that female birds do reduce their body burden of both PFOA and PFHpA through deposition to eggs.

63-2 TIMMER, CM*; BERGMAN, DA; Grand Valley State University; *timmchri@mail.gvsu.edu*

From the dinner pot to smoking pot; how a better understanding of cannabidiol could alleviate anxiety and modulate hunger

Anxiety affects approximately 1/3 of the US population and presents in many different forms, ranging from social to panic disorders. It also presents with high comorbidity for other mental disorders. One treatment is Selective Serotonin Reuptake Inhibitors (SSRIs) which allow for increased activation of serotonin (5-HT) receptors. SSRIs come with an extensive list of side effects, which can fail to maintain quality of life. Cannabidiol (CBD) is a cannabis derived compound which has been shown to decrease anxiety by activation of multiple subtype 5-HT amine receptors. CBD has few side effects, is not psychoactive, and exhibits anti-psychotic properties. CB1 receptors can have bound CBD where it acts as an allosteric inhibitor of anandamide resulting in decreased drive for food. The current understanding of CBD's mechanisms is limited specifically in invertebrates where to date limited published articles involve behavior and cannabinoids. Decapod crustaceans, specifically crayfish, have emerged as a novel approach to studying drugs of abuse. Within the neural structures of the crayfish tails are 5-HT receptors that control tail-flips, a withdraw reflex when placed into a fight. Serotonin has also been linked to aggression and decision making for engaging in fights with other crayfish. Additionally, evidence currently suggests CB1 receptors are present at neuromuscular junctions (NMJ) and may have an impact on mobility. We are evaluating CBD effects on the NMJ. Crayfish administered with CBD or 5HT will have physiological recordings of tail tissue, assessment of amount of food consumed, and determine if CBD alters aggression and time spent engaging in paired fights of equal size. Statistical analysis of CBD and 5HT treated crayfish behaviors will lead to better understanding of crayfish and how it could impact humans.

53-4 TINGLE, JL*; SHERMAN, BM; HIGHAM, TE; Univ. of California, Riverside, N/A; *jessica.tingle@email.ucr.edu*

Body Size and Shape Influence Kinematics of Sidewinding Locomotion in the Rattlesnake Crotalus cerastes

Size plays a major role in how organisms move through their environments. Children negotiate obstacles differently than adults do, and they also move their short legs at a much higher frequency to achieve the same speeds as walking adults. Many animals face these sorts of challenges as they grow. Controlling for size, morphology also matters for locomotion. We studied how body size and shape affect sidewinding locomotion in the rattlesnake *Crotalus cerastes*. We collected various morphological measurements and high-speed video for 73 sidewinders ranging in size from 8 to 272 g. Previously, we demonstrated that morphology scales isometrically, meaning young sidewinders are essentially miniature adults. New analyses show that the shape of the wave formed by the body during sidewinding also shows geometric similarity across sizes, but that other kinematic variables, such as the height lifted or duty factor for individual points along the body, scale with negative allometry. Differences in body shape such as elongation ratio or tapering affect kinematic variables such as acceleration, wavelength, and wave amplitude. These size and shape effects could play a role in habitat use as snakes grow, and they could also contribute to intraspecific behavioral differences.

93-2 TIRUMALAI, AS*; MCMAHAN, SB; HALL, SB; BISWAS, T; BHANDAWAT, V; Duke University, Loyola University of New Orleans; *ast32@duke.edu*

Neuromechanical Model of Fly Leg

Hexapod animal models, such as cockroaches and stick insects, have proven to be very useful in the development of biomimetic robots. To understand hexapod neural control and apply it to robots, we first need to understand both the biomechanics of insect limbs and the interplay between neural activity and limb actuation. We will investigate this problem in *Drosophila* because our knowledge of its genetics make it possible to investigate single leg control in completely intact animals. We began our investigation by estimating the passive properties of the limb: all motor neurons in tethered flies were optogenetically deactivated into a ‘passive' state where the only forces present are those produced by the tissue viscoelasticity and gravity. We use these passive kinematics to compute passive muscle torques and determine the fly's joint tissue material properties, namely the torsional modulus and damping constants. Our experiments reveal that the cuticle and passive muscles at the Coxa-Femur and Femur-Tibia joints function as linear angular springs with some viscosity. Next, we model the 3D kinematics of the fly's legs using an actuated damped spherical double pendulum which we derive using Lagrangian mechanics. This model accounts for all of the torques present in the passive case, and actuation is provided by a spiking neuronal network which modulates the stiffness of springs in the joints of the pendulum model. We fit this model to 3D data from actively moving flies suspended from a tether. Finally, we describe how the model recapitulates neural control of fly leg kinematics using mutual information and transfer entropy, which describe correlation and informational flow between observable signals, respectively.

126-3 TITUS, BM*; MEYER, C; BERUMEN, ML; BARTHOLOMEW, A; REIMER, JD; YANAGI, K; RODRIGUEZ, E; American Museum of Natural History, National Museum of Natural History, King Abdullah Univ. of Science and Technology, American University of Sharjah, University of the Ryukyus, Natural History Museum and Institute- Chiba; *bentitus3@gmail.com*
Systematics and Species Delimitation of the Clownfish-Hosting Sea Anemones: Are There Really Only 10 Host Species?
The relationship between clownfishes and sea anemones is one of the most recognizable examples of symbioses on the planet. There are 30 described species of clownfishes, which have adaptively radiated to live with sea anemones, but only 10 nominal species of host anemones. Why does the diversity of clownfishes exceed that of the host anemones? Given the co-dependent nature of the mutualism, their broad geographic and ecological distribution, and that all 10 host species are only described morphologically, we hypothesize that many host anemone species are cryptic species complexes. We use the bubble-tip sea anemone *Entacmaea quadricolor*, the species that hosts the greatest number of clownfishes, as a case study to demonstrate the extent to which species level diversity in host anemones is likely underdescribed. Using samples spanning the entire geographic range of *E. quadricolor*, we take a molecular species delimitation approach using traditional and high-throughput sequencing to demonstrate that *E. quadricolor* harbors at least three cryptic species. These include an endemic species in the Red Sea, and lineages in the Indian and Pacific Oceans, respectively. Our slowly evolving Sanger sequence dataset recovers a fully supported (Red Sea, (Indian Ocean, Pacific Ocean)) topology, suggesting the *E. quadricolor* complex has an ancient Paratethyan origin that likely pre-dates the origin of the clownfish symbiosis. These are the first data that suggest the presence of cryptic host anemone diversity in the clownfish symbiosis. Our findings have important implications for our understanding of the evolution of the entire symbiosis

P1-237 TIVEY, TR*; COLEMAN, TJ; WEIS, VM; Oregon State University; *ttivey@gmail.com*
Symbiont-specific recolonization patterns in a cnidarian-algal symbiosis
In cnidarian-dinoflagellate endosymbioses, algal symbionts must colonize host tissues and proliferate within cnidarian host cells. Despite the importance of colonization, little is known about the cellular mechanisms that govern the rate of proliferation and pattern of colonization of symbionts through host tissues. To explore these colonization patterns we used the sea anemone Aiptasia and its symbiont partner alga from the family Symbiodiniaceae. To capture symbiont proliferation dynamics within Aiptasia tentacles we used an epifluorescence microscope to rapidly and repeatedly image live Aiptasia and monitor symbiont colonization. We estimated the number of symbionts within each symbiont cell cluster, indicating localized proliferation as opposed to symbiont migration through the gastrodermal tissue or gastrovascular cavity. We also tracked total cluster number, density, and location within tentacles. To determine the effect of temperature stress on colonization dynamics, we inoculated Aiptasia with *Breviolum minutum*, a homologous symbiont to Aiptasia. We imaged partially colonized anemones for one week and then exposed half of the anemones to a sublethal temperature stress of 32 C. In combination with temperature stress, we further examined colonization processes using heterologous symbiont species and found differences in the rate of symbiont cluster formation, symbiont density, and response to temperature stress. In summary, our results describe the rate of formation and growth of different sized symbiont clusters (singlets, doublets, etc.), and indicate the importance of new cluster growth to colonization. These symbiont colonization patterns will hopefully enable us to better understand processes involved in the initiation of symbiosis and recolonization after periods of dysbiosis.

P2-234 TO, KHT*; GIGNAC, PM; O'BRIEN, H; STOCKER, M; Virginia Tech, Oklahoma State University Center for Health Sciences, Tulsa; *khanhto@vt.edu*
Cranial musculoskeletal study of black-throated finch (Aves: Passeriformes: Estrildidae)
Cranial kinesis, the movement of cranial bones in relation to the neurocranium, requires the coordination of muscles and ligaments to finely move the bill and mandible. These soft tissues are often extremely small, making studying their growth and development in many groups difficult, especially for taxa with convoluted musculature and small body size such as Passeriformes. We used micro-computed tomography (μCT), diffusible iodine-based contrast-enhanced CT imaging, and digital dissection to study and quantify the ontogeny of mandibular and kinetic musculature in the passerine jaw (black-throated finch, Poephila cincta) for comparison to a common non-passerine model (domestic chicken, Gallus gallus domesticus). Notably the altricial finch had more muscle partitioning than the precocial chicken, particularly among *Musculus adductor mandibulae*. This was apparent throughout ontogeny, indicating that the passerine jaw adductor and protractor bauplan is set relatively early in development. Such partitioning, seen in several species of finch, is a hallmark of passerine jaw anatomy. Ontogenetic shifts in muscle mass were unexpected in our dataset, however. For example, absolute jaw muscle mass was reduced in the adult finch as compared to the fledgling individual. This may be from low sample size, or it may represent the peculiarities of avian life-history patterns (e.g. displaying males often show declining body mass with courtship, and females demonstrate similar declines associated with parental care). Thus, selecting specimens from outside of the breeding season is likely crucial for obtaining high-quality, comparative data that includes quantifying functional anatomical features in birds.

P2-166 TOBIN, K*; ANDERSON, K; CORNELIUS, E; VéZINA, F; JIMENEZ, A.G.; JIMENEZ, ANA; Colgate University, Université du Quebéc à Rimouski, Université du Quebéc à Rimouski; *ajimenez@colgate.edu*
Environmental Mismatch During Cold Shock in Black-capped Chickadees and Its Effects on Tissue Oxidative Stress.
Maximal thermogenic capacity (Msum) in wild black-capped chickadees suggests that phenotypic adjustments are slow and begin to take place before winter peaks. However, when mean minimal Ta reaches -10°C, birds' phenotype appears to provide enough reserve capacity in cold endurance to buffer days with Ta of -20°C or below. This would imply that reserve capacity could also affect other systems. For example, birds could maintain a higher antioxidant capacity as part of their cold acclimated phenotype. In terms of oxidative stress, this may mean that RS (reactive species) production associated with increases in metabolic rate for thermogenesis would remain below antioxidant capacity in cold-acclimated birds to avoid damage during periods of high metabolic rate. Here, we tested how environmental mismatch affected oxidative stress by comparing variation of specific parameters in cold acclimated (-5°C) black-capped chickadees exposed to a 15°C drop in temperature (treatment; -5°C to -20°C) to that of control individuals (remaining at -5°C). We measured sodium dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) activities, as well as lipid peroxidation (LPO) damage, and antioxidant scavenging capacity in pectoralis muscle, brain, intestine and liver. We found that SOD, CAT and GPx varied with regards to tissue type. LPO did not differ by treatment, tissue or treatment*tissue. Peroxyl varied with regards to tissue type. Hydroxyl varied with regards to tissue and treatment*tissue. Control liver hydroxyl values were marginally higher than treatment liver values and control muscle hydroxyl values were lower than treatment muscle values. The increase in OH scavenging capacity during cold shock in muscle could be related to an increase in food intake.

S10-4 TOBIN, Kerrigan; SADD, Ben M.*; Illinois State University, Normal, IL; *bmsadd@ilstu.edu*

In the Heat of the Moment: Host Immunity and Parasite Resistance in the Face of Thermal Shifts and Stress

Thermal extremes and abrupt shifts in temperature will impose physiological stress on organisms, and may increase susceptibility to other extrinsic factors, such as disease. It has been implied that ongoing changes in the thermal environment are negatively influencing bumble bees and their functioning as key pollinators, but we have limited information of causal effects of temperature on relevant measures of bumble bee health. To fill this void, we have used the model host-parasite system of bumble bees and their trypanosome parasite *Crithidia bombi*, together with life history and immune measures. We have specifically investigated the thermal mismatch hypothesis, which predicts reduced performance following an abrupt shift away from an acclimation temperature, and the thermal stress hypothesis, which suggests costs experienced under extremes will compromise an organism's ability to function, including the fighting of infections. Results suggest that infection outcomes may be robust to thermal variability within the range of normal daily temperatures, but that exposure to realistic heatwaves can be detrimental to bumble bee immunity and other fitness-related traits. Underlying these effects may be antagonistic relationships between the heat stress and immune responses. Overall, the results suggest that thermal variability will have important consequences for bumble bee physiology and biotic interactions, and with ongoing climate change these effects could compound with other bumble bee life cycle effects to the detrimental of fitness and population health.

106-6 TOBLER, M*; CULUMBER, ZW; Kansas State University, University of Alabama in Huntsville; *tobler@ksu.edu*

Parent-Offspring Conflict, Ecology, and Life History Diversification in Livebearing Fishes

Major shifts in life history evolution - such as the transition from pre- to post-fertilization maternal provisioning in viviparous organisms - require complex morphological and physiological adaptations. The conditions under which these striking transitions arise remain unknown. Theory postulates that parent-offspring conflict can drive diversification in maternal provisioning strategies, but alternative hypotheses focusing on sexual selection and ecological adaptation have been neglected. We use comparative phylogenetic methods with 94 species in the family Poeciliidae to show that repeated shifts from lecithotrophy (pre-fertilization provisioning) to matrotrophy (post-fertilization provisioning) preceded concomitant changes in sexual selection, establishing a previously missing causal link between shifts in life history and mating systems. Bi-directional evolution along the lecithotrophy-matrotrophy continuum is not consistent with conflict hypotheses that predict ever increasing levels of matrotrophy once post-fertilization provisioning evolved. We also showed that variation in matrotrophy was correlated with high primary productivity and low competition, consistent with predictions of theoretical models of ecological adaptation. We propose a novel paradigm of matrotrophy evolution, emphasizing interactions between conflict-mechanisms and ecological sources of selection. Specifically, natural selection mediated by resource availability may counterbalance evolutionary trends mediated by parent-offspring conflicts. Under this paradigm, bi-directional evolution in maternal provisioning strategies is a mere consequence of shifting balances between natural selection favoring lecithotrophy and conflict-fueled increases in matrotrophy.

P1-121 TOKAR, DR*; MILANO, L; KARJASEVIC, A; HATLE, JD; Univ. of North Florida; *jhatle@unf.edu*

Characterizing the activation of Target of Rapamycin pathway in Lubber Grasshoppers in response to alteration of diet

Dietary restriction (DR) is known to increase lifespan. Recent work has concluded that protein restriction is more effective at extending lifespan than DR. Amino acids in proteins, especially branched chain amino acids (BCAAs), stimulate a major cellular growth pathway, the Target of Rapamycin (TOR) pathway, resulting in growth but also accumulated damage. This has been observed in a wide range of organisms, from *S. cerevisiae* to *D. melanogaster* and *M. musculus*. In mammals, increased BCAA consumption activates proteins of the TOR pathway, while reduced BCAA consumption has beneficial effects such as improved glucose tolerance and decreased fat levels. To further investigate the role of BCAAs in life-extension, Eastern lubber grasshoppers (*Romalea microptera*) were fed different quantities of lettuce and supplemental BCAAs in a 2 x 2 design. Treatment groups were: DR lettuce & BCAAs, DR lettuce & buffer, ad libitum lettuce & BCAAs, or ad libitum lettuce & buffer. BCAA supplementation was equivalent to the BCAAs in the additional lettuce consumed by ad libitum grasshoppers in comparison to DR grasshoppers. In two similar studies BCAAs were administered for ~50 days (1/3 of the normal lubber lifespan). DR lettuce & BCAA grasshoppers, in comparison to DR lettuce & buffer grasshoppers, had significantly increased isoleucine in the hemolymph ($P=0.042$). There was a similar trend for leucine and valine ($P=0.105$). These data suggest our dietary regimens successfully altered the BCAA availability in the grasshoppers. Molecular analyses such as Western blot will determine the degree to which proteins in the TOR pathway have altered phosphorylation. Transcript levels for proteins will also be quantified to further characterize the TOR pathway when the diet of an insect is altered.

P3-157 TOMPKINS, ET*; ANDERSON, DJ; Wake Forest University, Winston Salem, NC; *emtompki@gmail.com*

Breeding Responses to the El Niño Southern Oscillation are Age- and Trait- Dependent in a Long-Lived Seabird

Breeding responses to environmental quality may be age-dependent, with implications for population dynamics under environmental change and our understanding of the ageing process. We investigated relationships between age, reproductive performance, and the El Niño Southern Oscillation (ENSO; the dominant mode of interannual climatic variation in the eastern tropical Pacific) in a long-lived Galapagos seabird, the Nazca booby (*Sula granti*) using 18 years of longitudinal data from known-age females. Breeding date, clutch size, and offspring production were modeled as a function of age, sea surface temperature (SST, an index of ENSO) and their interaction, among other predictors. All breeding traits varied with age. Performance first improving during early life then declining in late-life. Clutch size increased linearly with SST while the relationship between offspring production and SST was hump-shaped (warm and cool SST extremes each depressed fledging success relative to neutral conditions). Age interacted with sea surface temperature to explain variation in all breeding traits. Considering early life, SST values associated with poor average performance increased the performance discrepancy between young versus middle-aged individuals for clutch size and breeding date. Differences in the fledging success of middle-aged versus old females were also greatest in poor environmental conditions, although the opposite pattern (smaller age effects in poor breeding environments) occurred for breeding date. Age influenced the direction and magnitude of individuals' responses to climatic variation; patterns were complex and trait-dependent and are discussed with respect to age and environment acting on the constraints individuals' face and their optimal reproductive effort.

112-5 TONG, C.S. D*; CHAN, K.Y. K; Hong Kong University of Science and Technology , Swarthmore College;
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Temporal variability modulates pH impact on larval sea urchin development
Coastal organisms reside in highly dynamic habitats. Global climate change is expected not only to alter the mean of the physical conditions experienced in these habitats, but also the frequencies and/or the magnitude of fluctuations of these environmental factors. One such factor is pH of the ambient water. There is an increasing number of studies that investigate if diel variations in pH would alleviate the impact of ocean acidification. However, no study to date has studied the role of frequencies and initial conditions of the fluctuations on organismal performance. Here, we exposed larval sea urchin *Heliocidaris crassispina* to constant and fluctuating pHs. Consistent with published results, reduced pH alone (pH 7.3) did not affect larval mortality but reduced the growth of larval arms in the static pH treatment . The relative negative impact of changes in pH, computed as Log Response Ratio, on larval arm was smaller when larvae were exposed to pH fluctuations, especially when the pH change is not frequent (48 hr vs 24 hr cycle). Our observations further highlight that larval urchin are particularly sensitive to changes in pH during the first 24 hours of development: such that larvae exposed to the control condition (pH 8.0) during the first day performed better than those first experienced the low pH (pH 7.3). Our observations suggest that larval responses to climate change stress could not be easily predicted only from exposure to mean conditions. Instead, further work on understanding the rate of physiological response as well as the real-time environmental conditions along the dispersive pathway is key to predicting organismal responses in the future ocean.

P2-129 TORJMAN, BZ*; MULLINEAUX, LS; MEYER, KS; WHEELER, JD; PECHENIK, J; Muhlenberg College, Woods Hole Oceanographic Institution, Swiss Federal Institute of Technology, Zurich, Tufts University; *bt250902@muhlenberg.edu*
Food affects swimming behavior of larval Crepidula fornicata
The slipper shell, *Crepidula fornicata*, is an ecologically important species with strong impacts on its surrounding community. It is native to New England but invasive on the west coast of North America and in Europe. *C. fornicata*, like many other invertebrates, develops via a swimming larval stage. Their swimming and feeding are both accomplished using the velum, meaning that larvae must alter their swimming behavior to feed successfully. We explored the swimming behaviors of larvae when feeding and how food availability can influence these behaviors. Larval swimming was recorded and tracked during different levels of nutrition: continuous feeding versus 4-day starvation prior to the experiment, and food present during the experiment or not. In treatments with food present, larvae (both fed and starved prior to the experiment) spent more time at the tops of experimental flasks. When food is available, larvae may prioritize feeding and remain in their planktonic stage for longer, whereas those without food present may settle and transition sooner to juvenile feeding strategies. Starved larvae swam more slowly than fed larvae, spent more time near the bottom, and consumed less food than previously-fed larvae. Thus, emaciation may cause ineffective swimming even when food is available. This study provides the first description of swimming and feeding behavior of *C. fornicata* larvae and marks an important step in developing this species as a model organism for studying larval feeding behavior and larval ecology.

36-1 TORSON, A/S*; DOUCET, D; ROE, A/D; SINCLAIR, B/J; University of Western Ontario, London Ontario, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario; *atorson@uwo.ca*
Overwintering of the Asian long-horned beetle: Metabolic rate, cold tolerance, transcriptome, and metabolome
An insect's capacity to survive low temperatures throughout winter is critical for range expansion in temperate regions. To cope with these stresses, many insects enter a state of developmental arrest known as diapause. The Asian longhorned beetle (*Anoplophora glabripennis*) is a wood-boring, forest pest species native to China and the Korean peninsula that has a complex life history spanning one to three years. ALB can overwinter as eggs or any larval instar, but little is known about its overwintering physiology. In this study, we measure metabolic rates, thermal sensitivity and cold tolerance strategy of ALB larvae from an invasive, North American population before, during, and after exposure to chilled temperatures. We then use this initial characterization to inform targeted metabolomics of larval hemolymph and fat body and tissue-specific RNA-seq of subesophageal ganglion, midgut, hindgut, Malpighian tubules, and fat body.

P1-164 TOTH, A J*; EVANGELISTA, D E; United States Naval Academy; *m196438@usna.edu*
Can we redirect a crowd by seeding it with informed leaders?
When considering the collective behavior of large groups, such as human crowds in physical or cyber spaces, schools of fish, large flocks of birds, etc., a natural question to consider is what it would take to change the direction of motion of the group. We will discuss simulations and initial experiments with Naval Academy midshipmen to test whether "informed" leaders, seeded within the group with an unannounced but coordinated agenda, can adequately alter the motions of the group. We will consider both the number and physical location of the informed leaders (spread throughout, or at the periphery) within the crowd. Testing with live midshipmen is, by necessity, limited to small numbers, so we will also use crowd simulations to explore the scaling effect of crowd size as well as the effect of a calm versus agitated state. We will also consider the relevance of such results to public safety, civil applications, and cases where it is desired to alter or redirect a swarm or flock.

69-1 TRAN, LL*; BUTLER, MA; University of Hawaii at Manoa; *leontran@hawaii.edu*

Color variation and the diversification of Megalagrion damselflies

Identifying conspecifics from heterospecifics is an important task in multi-species communities. Vision is an important modality for odonates where coloration may provide important signals for conspecific communication. The Hawaiian damselflies (*Megalagrion* spp.) compose an adaptive radiation that shows impressive color variation both between species and sexes. Male colors range from red to green, yellow, blue, violet, or black, often with multiple color patches within an individual. These damselflies have diversified into multiple habitat types, ranging from standing pools to high elevation streams to terrestrial vegetation, and are often found in multi-species communities. Therefore coloration may play an important role in the ecological diversification of this clade. We collected spectral reflectance measurements on the eyes, face, thorax, and abdomen of multiple species from five of the main Hawaiian Islands. In addition we measured reflectance of environmental substrates and sampled ambient light spectra. We conducted an analysis of color and contrast variation in multiple damselfly communities. The extreme color variation of this clade may provide key insights into the diversification of adaptive radiations.

P3-31 TRAVIS, KG*; HOFFMANN, SL; GIBB, AC; California State Univ., Long Beach, Florida Atlantic Univ., Northern Arizona Univ.; *kevin.travis@student.csulb.edu*

Give Me a Brake: Comparative Pectoral Fin Kinematics and Mechanics Across Sculpin Species

Braking ability in fishes is an important indicator of their ability to maneuver, evade predators, and colonize new habitats, especially across environmental gradients. Sculpins (Scorpaeniformes: Cottoidea) are a diverse group of benthic fishes ranging from subtidal to high intertidal habitats. The sculpin species living within and across these environments exhibit high morphological variation, especially in their pectoral fins. However, the functional implications of this interspecific variation have not been investigated. We measured the pectoral fin movements during braking of three sculpin species that come from different habitats and vary in fin morphology. We calculated the instantaneous change in fin angle and fin area as indicators of drag production, while changes in whole-animal velocity represented braking performance. Preliminary results suggest that the high intertidal species, *Oligocottus maculosus*, incorporated more fin area during braking and abducts the fin at greater angles, resulting in greater deceleration compared to the subtidal species. Additionally, full-fin passive-bending tests were used to determine the *in situ* stiffness of the fin rays for *O. maculosus* and one of the subtidal species, *Leptocottus armatus*. Preliminary observations suggest that the fin is mechanically regionalized in *O. maculosus* (that is, the rays show different degrees of resistance to bending), and *L. armatus* appears to have greater resistance to bending overall. High-intertidal sculpin species may perform better at braking and have regionalization of fin mechanical properties that allow them to inhabit highly complex tidal zones. Ongoing analyses of sculpin pectoral fin kinematics and their mechanical properties will provide insight into how ecology, behavior, morphology, and mechanical properties change along environmental gradients.

P3-57 TRAVITZ, LS*; MORAN, CJ; GERRY, SP; COUGHLIN, DJ; Widener University, Chester, PA, The Citadel, Charleston, SC, Fairfield University, CT; *lstravitz@widener.edu*

Seasonal Changes in Pectoral Fin Muscle Histology in Temperate Labrid Fishes

Cunner (*Tautogolabrus adspersus*) and tautog (*Tautoga onitis*) are temperate wrasses with different strategies for overwintering. While cunner enter torpor during winter, tautog migrate off shore into stable deep-water habitats. Previous work has shown significant decreases in muscle and locomotor performance at temperatures ≤10˚C. In the present study, we use immunohistochemistry with fast and slow myosin heavy chain antibodies to explore how the muscle fiber composition of the abductor superficialis varies across a range of thermal acclimation temperatures in these two species. The abductor superficialis powers the thrust-generating downstroke in these labriform swimming fishes. Preliminary analysis reveals that the bulk of this muscle is composed of a fast-twitch fibers while the slow-twitch muscle fibers are distributed in a discrete slip along one edge of the abductor superficialis. This work will explore how the relative amount of fast- and slow-twitch varies with thermal acclimation in cunner and tautog. To maintain performance in winter would require a relative increase in the contribution of fast-twitch fibers. For instance, tautog may differ from cunner in their pectoral muscle fiber distribution due to differences in over-wintering behavior.

S9-11 TRAYLOR-KNOWLES, Nikki G. *; VANDEPAS, Lauren; BROWNE, William E. ; University of Miami, Rosenstiel School of Marine and Atmospheric Sciences, University of Washington, University of Miami; *ntraylorknowles@rsmas.miami.edu*

Ctenophore Immunity: A Journey Into The Unknown

Innate immunity is an ancient physiological response critical for protecting metazoans from invading pathogens. It is the primary pathogen defense mechanism among invertebrates. While innate immunity has been studied in many different marine organisms including molluscs, crustaceans, and cnidarians, this important pathogen defense mechanism has not been characterized in ctenophores. The ctenophores comprise an exclusively marine, non-bilaterian lineage that diverged early during metazoan diversification. The phylogenetic position of ctenophore lineage suggests that characterization of the ctenophore innate immune system will reveal important features associated with the early evolution of the innate immune system. Here we present an analysis of genetic components of the ctenophore innate immunity pathway. We also have used cell biological approaches to identify and characterize ctenophore phagocytes that display macrophage-like behavior when challenged with a pathogen. We discuss the implications of these findings in ctenophores and how they inform our understanding of the evolution of the metazoan innate immune system.

P3-15 TSENG, ZJ; GRABOWSKI, C*; University at Buffalo; *jacktsen@buffalo.edu*

A Cost-Effective System for Capturing Chewing Movements Using Small Fluorescent Paper Markers

Commercial 3D motion-tracking systems are readily available, albeit expensive, options for motion research in comparative biology. Most applications using these devices are in whole-body or whole-limb model systems. The extent to which smaller-scale, finer movements can be captured precisely with such systems is limited by factors such as marker size, and the ability of markers to non-invasively track movements without impediment. Motion capture markers in commercial systems range from 3 to 25 mm in diameter, many of which may be inadequately sensitive to smaller-scale movements that occur in motions such as chewing. We designed and tested a cost-effective alternative to commercial turn-key systems for capturing jaw motion in mammals. Using a VROMM (Video Reconstruction of Moving Morphology) based approach, we analyzed the precision and accuracy of a motion capture system based on videos of 3 mm diameter fluorescent paper markers, recorded by two synchronized cameras coupled with blue light filters and blue LED light source to enhance marker-to-background contrast. Using free software (XMALab and R) and custom scripts, our protocol achieved a mean reprojection error of 0.23 pixels. This value translates to a mean accuracy level of 0.04 mm, more than twice as accurate as those reported for several mainstream commercial systems (0.10 to 0.30 mm). For angular measurements, our protocol achieved an accuracy of <1 to 2 degrees. These experimental results suggest that this relatively simple and cost-effective protocol has comparable or lower levels of measurement error compared to commercial systems, and could be suitable for kinematic studies of finer-scale movements in model systems with small ranges of motion. The non-invasive nature of the protocol makes it a viable alternative to expensive commercial systems for deployment in field or lab settings.

P1-2 TSUNEKAGE, T*; BISHOP, CR; LONG, CM; LEVIN, II; Agnes Scott College; *ttsunekage@gmail.com*

Integrating information literacy training into an inquiry-based introductory biology laboratory

Information literacy is an essential skill for biologists; however, most biology curricula do not intentionally integrate information literacy into classroom and laboratory exercises. There is increasing evidence that developing information literacy skills in undergraduates improves their research skills, writing, and GPAs. Our objective was to integrate information literacy skills into the first semester of Agnes Scott College's introductory biology class with a multi-week, inquiry-based laboratory module that leverages primary literature. We describe our approach to incorporating information literacy and the module we have developed, which challenges students to develop and test a hypothesis related to parental care behavior in barn swallows (*Hirundo rustica erythrogaster*). Students form their hypothesis based on the literature searching done during the information literacy session led by college librarians, produce an annotated bibliography, collect and analyze video data of barn swallows feeding their offspring, and present their findings as a three-minute 'lightning talk'. Our analysis of students' annotated bibliographies indicates that 80% of the papers referenced in the bibliographies were appropriate for developing the specific hypotheses that students would test in the following weeks. The key elements of a successful information literacy training plan include faculty-librarian collaboration, multiple classroom or laboratory sessions that introduce or utilize information literacy, and relevance of the information literacy training to an assignment or exercise. Ideally, by introducing information literacy early in biology curricula, departments can develop tiered information literacy plans within the biology major that incorporates opportunities for students to use and refine these skills throughout their studies.

93-5 TUCKER, EL; XI, S*; QUINN, BL; HSIEH, ST; Temple University, Harriton High School; *sthsieh@temple.edu*

Quantifying dynamic stability in six, seven, and eight-legged running spiders

The maximum Lyapunov exponent method is commonly used for quantifying dynamic stability in humans, by quantifying the average rate of the log of divergence following a small perturbation. Its advantages include being able to calculate Lyapunov exponents from any type of kinematic data, its ability to preserve time variant components in its analyses, and its relative simplicity of implementation. However, it has for the most part been applied in situations in which it is possible to acquire large datasets (i.e., 100-250 continuous strides) of fairly repeatable data (e.g., walking on a treadmill) and controlled speeds. These conditions are not realistic in typical comparative biomechanics studies, which more commonly have multi-legged animals running freely through a field of view with 10 or fewer strides in a single trial, and therefore has not been implemented in a 2+ legged system, as far as we are aware. In this study, we have successfully applied the maximum Lyapunov exponent approach to a freely-moving octopedal system (Guatemalan tiger rump tarantulas, *Davus pentaloris*), for which five or fewer continuous strides were available in each trial. Embedding dimensions were calculated for control and autotomy trials, and a standard time lag of 10 samples was used for all reconstructed state-space. Multiple trials were concatenated to maximize the number of complete strides analyzed and each time series was standardized to an average of 100 samples per stride. We characterized dynamic stability as the maximum (short-term) Lyapunov exponent. Lyapunov exponents were calculated independently for each leg.

P3-35 TUMMINELLI, AN*; BARTOL, IK; Old Dominion University, Norfolk, VA; *atumm002@odu.edu*

Fin Motion Diversity in Squid During Turning

Squid use an integrated fin/jet system powered by muscular hydrostats to swim. The fins are capable of diverse movements with high degrees of freedom and provide propulsive and control benefits that complement the vectored jet system. The complex fluid-structure interactions associated with the fins pose unique challenges for researchers, particularly during turning maneuvers when the fins are especially active. To better understand fin movements and flow generation during turns, we used proper orthogonal decomposition (POD) and defocusing digital particle tracking velocimetry (DDPTV) to study the brief squid *Lolliguncula brevis*; and the longfin squid *Doryteuthis pealeii*; as they performed maneuvers in a viewing chamber. Both flap and wave components were present in all fin motions, but the relative importance of the wave components changed with swimming orientation and turning behavior. Fin wave components were generally more prominent during arms-first turns and during controlled tight turns. While a diversity of fin wake patterns was observed, the most complex fin wakes with interconnected vortex structures correlated most closely with fin movements with significant undulatory characteristics. Our results demonstrate that fin motions are diverse and an integral complement to the jet during turning behaviors and our integrative POD/DDPTV approach can be a powerful tool for decoupling fin motions and understanding their momentum consequences.

99-2 TUNE, T*; IRVING, T; SPONBERG, S; Georgia Tech, Illinois Tech; *ttune3@gatech.edu*

X-Ray Diffraction Resolves how Lattice Spacing Explains the Workloop Differences of Two Muscles with Identical Steady State Properties

Muscle is energetically versatile, achieving widely varying work outputs depending on the task. Many steady state measurements of muscle properties (force-length, force-velocity, and twitch response) are used to predict how it will behave under dynamic conditions. However, even when these properties are known, it can still be impossible to predict dynamic workloops. Two muscles in the cockroach, *Blaberus discoidalis* have nearly identical classical steady state muscle properties and share innervation, but one is a brake and one is a bifunctional motor. Previously, we discovered the first consistent difference between these two muscles - a 1 nm difference in the actin-myosin spacing within their sarcomeres. However, it is still unclear how these passive differences could affect muscle dynamically without causing differences in their steady state macroscopic behavior. Using the BioCAT x-ray beamline at the Advanced Photon Source at Argonne National Lab, we measured the lattice spacing of both muscles during dynamic workloops and isometric twitches. We found that in isometric twitches, one muscle's lattice spacing increased to the same value as the other muscle, causing the spacing difference to vanish under steady state conditions. A difference in spacing under passive but not active conditions means that during cyclic workloops the lattice spacing changes were larger in one muscle than the other. This increased transient correlated with an earlier and higher rise in force that enables a region of positive work in the workloop. A 1 nm transient difference in actin-myosin spacing mediates the difference in the work output of the two cockroach muscle but also predicts their identical quasi-static properties. These results indicate that multiscale dynamics from the nanoscale to the macroscale can mediate categorical changes in muscle function during locomotion.

P3-28 TURNBULL, KF*; MCNEIL, JN; SINCLAIR, BJ; University of Western Ontario; *kturnbu9@uwo.ca*

Does the Energetic Cost of Burrowing through Different Soils Determine Insect Overwintering Site Selection?

Burrowing through soil is among the most energetically costly forms of terrestrial locomotion. Many temperate insects burrow to protected sites beneath the soil surface prior to winter dormancy. Because soil buffers the effects of air temperature, insects that overwinter deeper underground may exploit mild, thermally-stable microclimates. However, the benefits of deeper sites could trade-off with the energetic costs of entry and exit from soil, constraining insects to shallow sites if moving through the soil is costly. To test this hypothesis, we used the western bean cutworm, *Striacosta albicosta* (Lepidotera: Noctuidae) which burrows deep into soil to overwinter. Using two artificial soils that varied in clay content, we described the burrowing behavior of the cutworms, and examined the effect of soil properties on the net cost of burrowing. The distribution of overwintering sites was measured in each artificial soil, and in two natural soils in the field. Initial results suggest that cutworms penetrate further into soils with lower clay content. Our work will provide insight into the costs of burrowing into soil to overwinter: a strategy used by many temperate insects.

P3-131 TURNER, MK*; TIATRAGUL, S; HALL, JM; WARNER, DA; Auburn University; *MKT0018@auburn.edu*

Testing Different Methods for Creating Ecologically-relevant Incubation Temperatures in the Lab

Ecological studies of reptile development traditionally employed constant incubation temperatures to assess the effect of temperature on embryos and hatchling phenotypes. Constant temperature regimes do not accurately represent natural thermal fluctuations in nests. With the advent of programmable incubators, researchers can simulate nest conditions in the lab. A common method is to construct daily temperature regimes by averaging temperatures recorded at each hour of the day by temperature sensors across multiple nests. Calculating hourly means over multiple nests, however, may obscure some of the variation that exists in natural nests since microenvironmental conditions affect how nest temperatures rise and fall at different rates across the landscape. To address this, we used temperature data recorded from 22 nest sites of anole lizards (*Anolis cristatellus* and *Anolis sagrei*) over a period of 43 days. We created two 24-hour daily temperature fluctuations. One was created by taking hourly mean temperatures across all nests. A second used the same nest data, but we first aligned the peak temperatures of each nest prior to calculating hourly means. This method better approximates the natural daily rise and fall of temperature. These regimes had the same mean temperature but differed in how rapidly temperature rose and fell throughout the day as well as the maximum daily temperature. We randomly distributed eggs from a captive colony of anoles to incubate at each regime and measured developmental rate, water uptake, and hatchling morphology. We found no significant effect of incubation treatment on developmental rates, water uptake, or hatchling phenotype for either species. Our results suggest that researchers have some flexibility in how they replicate nest conditions in the lab.

P2-241 TURNER, MS*; DONATELLI, CM; Univ. of Washington, Seattle, Tufts University, Boston; *msturn@uw.edu*

#Scanallstars: Comparison of the Calcareous Endoskeletons of Sea Stars Using High Resolution 3D Imaging and Fractal Analysis

Sea stars, echinoderms of the class Asteroidea, are found in all ocean basins from the intertidal to the abyssal zones. Members of this class are radially symmetric as adults and contain an endoskeleton composed of small calcium carbonate spines called ossicles.This endoskeleton supports diverse morphologies among this group, with ossicle shape varying from spines to plates. Although the ossicle structure has been compared using 2D x-rays, little work has been done to compare their organization in three dimensional space. We took high resolution micro-CT scans of nine species of stars that live around the San Juan Islands in Washington, USA. We modified a fractal analysis technique called box counting for application to 3D data to measure the complexity of the ossicle structure. The scans revealed a huge diversity in the composition of the ossicles, which varied in shape, size and arrangement. Three dimensional fractal analysis indicated highly complex organization of ossicles across all sea star endoskeletons. Using a fractal number scale of 0 to 4, 4 being the most complex, the stars included in this study ranged from 3.3 to 3.5. Ossicles may provide a range of functions for each species, including specialized prey capture, defense against predation, or habitat requirements. Future study could determine how differences in ossicle arrangement are related to the niches these species occupy.

P1-242 TWEETEN, KA*; EZENAGU, N; St. Catherine University; *katweeten@stkate.edu*

Genetic Analysis Supports Classification of Diploid and Polyploid Populations of Lumbriculus as Distinct Species

Diploid and polyploid populations of *Lumbriculus* were genetically compared through sequence analysis of mitochondrial 16S rRNA and cytochrome oxidase subunit 1 genes and the nuclear ITS and 18S rRNA genes. These genes are useful markers in the determination of phylogenetic relationships between organisms with differences in sequences being correlated with evolutionary divergence and speciation events. The populations examined were those, mostly from North American sources and natural habitats, that we have previously characterized using flow cytometry for DNA content and protein profiles, with results indicating that the diploid and polyploid populations should be classified as distinct species. DNA was isolated from the specimens of *Lumbriculus* and the marker genes were amplified using the polymerase chain reaction. PCR products were sequenced and then analyzed using genomics databases. Phylogenetic trees were constructed and showed that polyploid and diploid populations segregated into separate lineages. This genetic data was consistent with our biochemical data, further supporting the taxonomic separation of populations of *Lumbriculus* into at least two distinct species. Resolution of the taxonomy is important, as ploidy levels could impact interpretation of the results of physiological, transcriptomics, toxicological, ecobiology, and other studies being done using different populations from the *Lumbriculus* complex.

P1-233 TWELE, LR*; MOLINE, RE; MIDDLEBROOKS, ML; University of Tampa; *mmiddlebrooks@ut.edu*

Phototaxic Behavior Differs Between Kleptoplastic and non-Photosynthetic Sea Slugs

Sacoglossan sea slugs are a group of small herbivorous marine gastropods which typically are dietary specialists on green macroalgae. Several species of sacoglossan engage in kleptoplasty, the process of sequestering chloroplasts stolen from algae inside of the slug's own cells in order to photosynthesize. Because they gain energy from sunlight through photosynthesis, it is expected that photosynthetic sacoglossan species will spend more time in direct light than non-photosynthetic species. Phototaxic behavioral experiments were conducted on two species of long term photosynthetic sacoglossans and three species of non-photosynthetic sacoglossans. The photosynthetic species were significantly more likely to spend time in the light, demonstrating that photosynthesis provides a strong incentive for light exposure despite potential risks of predation. On the contrary, non-photosynthetic species either prefer shade or do not exhibit a strong phototaxic response. Examining differences between these two groups of slugs provides valuable insight into the impact that the evolutionary novelty of kleptoplasty has had on the ecology and behavior of these animals.

P1-150 TWOMBLY ELLIS, JF*; MARKLAND, S; AMBROSE, AF; ORTIZ ALVARADO, CA; GONZALES BETANCOURT, VH; BARTHELL, JF; PETANIDOU, TF; TSCHEULIN, T; ABRAMSON, CI; GIRAY, T; Cornell University, Oklahoma State University, Savannah State University , University of Puerto Rico, Kansas University, University of Central Oklahoma, University of the Aegean; *jt574@cornell.edu*

Color and Scent as Cues for Reward Association During Honey Bee Foraging

The European Honey bee, *Apis mellifera* , is a generalist and forages on many different flowers. In order to orient themselves to high reward sources *A. mellifera* uses the color and fragrance of flowers. The extent to which color and scent can be important is not well understood. This experiment seeks to determine if scent itself is a reward or if it is a learning cue. To conduct this experiment feeders were used to lure bees to an artificial flower patch with pink, blue, and white colored flowers. The bees were then subjected to series of different assays with varying sucrose molarities, color, and scent combinations. We found that the bees only visited flowers with scent more frequently than those without when the scented flowers had higher molarity solutions. Additionally, we found that when put through more than one phase the bees failed to modify their behavior to follow the higher reward. This shows that honey bees do not treat scent as a reward but they do use it as a learning cue. Furthermore, bees can be conditioned to use scent and/or color as a cue for the higher reward, but when presented with this cue without previous experience, or with contradictory previous experience, it is not recognized as a cue.

27-3 TYLAN, C*; LANGKILDE, T; Pennsylvania State University; *clh319@psu.edu*

Surviving the Invader: What Branches of the Immune System are Altered by Multigenerational Exposure to a Novel Predator?

Anthropogenic ecosystem alterations, such as the introduction of invasive species, are a common perturbation affecting many animals. Such stressors can have fitness-relevant consequences, including for immune function. The eastern fence lizard (*Sceloporus undulatus*) has been dealing with invasive stinging fire ants (*Solenopsis invicta*) for over 70 years and exhibit associated morphological, behavioral, and physiological adaptations. We conducted a suite of immune assays on lizards caught from sites with long histories of fire ant invasion and lizards from fire ant free sites. Our results build on earlier findings of suppressed immune function of lizards within fire ant invaded populations to show that some portions of the immune system are affected by a history of fire ant invasion (e.g. cell-mediated immunity), whereas others remain unaltered (e.g. superoxide production by phagocytes). We also found that lizards from fire ant invaded sites have a higher ectoparasite load than lizards from sites without fire ants, which can also affect immune function. This variability in the responses of different aspects of the immune system to invader-induced stress may reveal which portions of the immune system are most vital to survival, and those that may be sacrificed in times of elevated stress.

43-3 TYLER ROLLMAN, B*; TROY ROWAN, ; BEN RYAN, ; CAROL FASSBINDER-ORTH, ; Creighton University; *tylerrollman@creighton.edu*

Buggy Creek virus Dynamics within Swallow Bugs (Oeciacus vicarious)

Arthropod-borne virus (arbovirus) emergence and re-emergence has rapidly increased in recent years, causing a rise in arboviral-related mortalities and morbidities. Members of the Cimicidae family, such as human bed bugs (*Cimex lectularius & Cimex hemipterus*), typically do not transmit human viruses. However, cimicids are known to be alphavirus vectors in other mammalian hosts, implying they could be capable vectors for human viruses. Buggy Creek virus (BCRV) is a unique arbovirus transmitted by swallow bugs (*Oeciacus vicarious*), a cimicid ectoparasite, to cliff swallows (*Petrochelidon pyrrhonota*). Swallow bugs exist within cliff swallow nests year-round while cliff swallows are only present in the Midwest US during early summer to breed and raise young. This creates a large window of minimal blood meals for the bugs and no host for BCRV. While cytopathic viral levels correlated with this stagnant period, viral RNA levels remain relatively unchanged year-round, showing abnormal viral persistence. Monthly characterization of swallow bug and BCRV dynamics is needed for better understanding of this viral persistence in a non-typical insect vector. Samples of swallow bugs were collected monthly from five sites across southwest Iowa and southeast Nebraska. After sorting swallow bugs by age in each sample, the bugs were homogenized, and the homogenate extracted through a 0.22-micron filter. This filtrate was used to characterize the viral population found within the swallow bugs from this time point. Characterization of BCRV included infectious viral titer, cell toxicity and apoptotic activity due to BCRV, and viral RNA quantification and qualification. Results show BCRV virulence spikes and adult swallow bug populations plummet when the host is present, indicating a dynamic time within this system.

103-8 TYTELL, E.D.; Tufts University; *eric.tytell@tufts.edu*

How body shape and mechanics interact for swimming performance in (physical models of) fishes: Volumetric flow visualization, forces, and power

Fish bodies vary widely in shape, from streamlined torpedo-like fish to very flat, almost disc-like shapes, and many variations in between. Their bodies also differ in their internal mechanical properties: some fish have very stiff bodies, while others can be extremely flexible. How do these properties work together to influence the swimming performance of different fish species? A parameter called the "effective flexibility," which combines length, aspect ratio, stiffness, and bending frequency, has been shown to capture much of the dynamics of thrust production in flexible rectangular panels. It is not known how well it approximates the behavior of more complex bodies like those of fish. I used elastomer models of fish, based on the body shape of the bluegill sunfish (*Lepomis macrochirus*), to vary shape and material properties separately. I actuated the models using a single sting, rotating back and forth in the pitch axis, and measured thrust, lateral force, and mechanical power requirements. I also quantified the three-dimensional flow patterns behind each model using a TSI V3V volumetric particle image velocimetry system. For all models, all forces increase with increasing frequency. At frequencies that correspond to the same effective flexibility in different shape and stiffness models, the forces have a complex relationship with both shape and stiffness.

51-2 UEHLING, J.J.*; TAFF, C.C.; WINKLER, D.W.; VITOUSEK, M.N.; Cornell Univ.; *jju8@cornell.edu*

Early life conditions influence adult response to stressors in a free-living passerine

Early life conditions may have large impacts on the ways animals respond to stressors as adults; however, it is difficult to monitor most free-living animals over the course of their lives to assess the effects of these early conditions. Here, we test the prediction that environmental conditions experienced during critical developmental stages impact the hormonal mediators of the response to stressors in adults. To do so, we use a long-term dataset of Tree Swallows (*Tachycineta bicolor*) with records from both natal development and adult breeding. Specifically, we focus on how adults respond to stressors during incubation and provisioning of nestlings via corticosterone (CORT) responses because, in this population, adult CORT levels during these stages predict reproductive success. We saw no effect of developmental conditions on baseline CORT during incubation, or on baseline CORT or stress-induced CORT response during provisioning. However, we saw a negative relationship between average temperature during the incubation stage of development and stress-induced CORT response during adult incubation, suggesting that conditions during development can influence the way Tree Swallows respond to challenges as adults. We found no relationship between chick CORT phenotype and probability of fledging or recruitment, demonstrating that the relationships seen in adults are unlikely to result from differential survival of chicks with different CORT phenotypes. Fully understanding the mechanisms that link natal conditions to adult CORT phenotypes requires studies of juveniles post-fledging, a poorly understood life stage. Overall, our results suggest that early life conditions can have long-term impacts on individuals and their reproductive success.

80-2 UNSWORTH, CK*; TARCHICK, MJ; MCINERNEY, SJ; ASTLEY, HC; University of Akron; *cku3@zips.uakron.edu*

The Effects of Crocodilian Tail Serrations on Surface Water Disturbance

Semi-aquatic animals possess specialized morphological features that affect the hydrodynamics of locomotion. Crocodilians have laterally compressed, serrated tails used for propulsion in aquatic environments and balance during terrestrial walking, however the hydrodynamic function of tail serrations is unknown. Most crocodilians ambush terrestrial prey at the shoreline, which requires camouflage and stealthy movement in shallow water. We hypothesize that serrations disrupt large-scale flow structures from tail movements and correspondingly reduce visible surface disturbance. To test this hypothesis, we translated 14" long 3-D printed panels with evenly spaced triangular serrations directly under the water surface with a linear actuator; a panel with no serrations was used as a control. Waves were visualized by recording the reflection of a fan-beam laser on the water surface in the path of the panel using a GoPro HERO6. From the video of the laser reflection, a waveform was extracted, filtered, and processed using Continuous Wavelet Transform (CWT), which detects non-stationary spatial disturbances at a continuous range of frequencies. In our preliminary analyses, global power spectra were calculated from three videos each of serrated and control panels, with the magnitude of power positively correlating with visible surface disturbance. We observed a 27% decrease in magnitude of power from the control to the serrated panel indicating that serrations did reduce visible surface disturbance. Understanding the effects of serrations on fluid flow could contribute to bio-inspired noise or turbulence reducing engineered systems, while using CWT to characterize surface disturbance creates a unique framework to study interface dynamics in a three-phase system.

32-7 UNSWORTH, CK; ABUHASHIM, WA*; BRANNOCH, SK; SVENSON, GJ; ASTLEY, HC; University of Akron, Case Western Reserve University, Cleveland Museum of Natural History; *cku3@zips.uakron.edu*

Biomechanics of the Praying Mantis Foreleg Strike

Praying mantises (*Mantodea*) catch prey by rapid motion of their specialized forelegs, quickly ensnaring smaller insects. Due to the high speed requirements to catch quick prey items, a mantis must accelerate their limb segments rapidly, which depends upon mechanical power. While organisms can increase mechanical power output by increasing muscle mass, the alternative is to couple muscle with an elastic tissue to generate relatively greater power than could be attained with muscle alone. In this phenomenon, known as power-amplification, elastic potential energy is stored in elastic structures and rapidly released, resulting in power outputs beyond those of muscle, as seen in the flea jump. This research investigates the foreleg strike of the Chinese Mantis (*Tenodera sinensis*) capturing live prey (*Periplaneta americana*) to determine whether power-amplification is used in the mantis strike. In our preliminary data, we recorded two strikes at 700 frames/second with two Edgertronic high-speed cameras, tracked the points in three dimensions. In these strikes, the distal tip of the tarsus reaches an average maximum velocity of 0.746 m/s, with an average peak acceleration of 60.7 m/s^2. These values suggest purely muscular actuation, though further evaluation is needed using inverse dynamics to compute joint angular acceleration, torque, and power across individual foreleg segments (coxae, trochanter, femora, tibiae, tarsi) to identify coordination and control patterns and which joints are primarily responsible for generating power. The apparent lack of power amplification in *T. sinensis* forelegs suggests that trade-offs may preclude some animals from using it, such as the dual function of *T. sinensis* forelegs for both prey capture and locomotion.

P1-214 URGILES, VL*; SAVAGE, AE; University Of Central Florida; *vurgiles@Knights.ucf.edu*

Diversification of terrestrial frogs in a remote high altitude tropical hotspot.

The Ecuadorean Andes sustains one of the most remarkable frog diversifications. In this region, nearly one in three known species of amphibians belong to the *Pristimantis* genus, which contains the majority of the direct-developing terrestrial frog species. Although efforts are ongoing to understand the diversity of *Pristimantis* in the Ecuadorean Andes, large regions, particularly the high altitude ecosystems, remain poorly documented and speciation and diversity of this genus remain widely misunderstood. Within this context, an interesting taxon with many unresolved questions regarding the patterns and process of diversification is the *Pristimantis orestes* species complex which is distributed across Páramo landscape and montane forest in the eastern and western slopes of southern Ecuador. Although some species have been recently included within this group, the small number of samples, geographic regions and loci included in these previous studies have prevented any definitive conclusions from being drawn. Moreover, delimiting and identifying species within this group is problematic because of the lack of molecular data, most notably from holotypes and paratypes. In this work we present a new molecular phylogeny for the *P. orestes* complex, reflecting the complex evolutionary relationships and diversification of the group with morphological, biogeographical and molecular evidence to support several new terrestrial frog species, as a result of a three-year series of expeditions, conducted in the high elevation ecosystems of southern Ecuador between 2500 and 4500m of elevation. Our results identify previously unrecognized species and suggest that the species exhibit restricted distributions, driven by particular elevational and habitat associations.

105-7 USHERWOOD, JR; The Royal Veterinary College; *jusherwood@rvc.ac.uk*

The indiscrete walk-run transition and skewed forces of young children match peak power minimization, as is suitable for short bipeds

The muscles of smaller animals, with their briefer stance times, are disproportionately more challenged - compared with larger animals - by the demands of producing instantaneous power as opposed to mechanical work. A simple model is developed to find vertical force profiles and stance durations that minimize either limb mechanical work or peak power demands during bipedal locomotion. The model predicts that work minimization is achieved with a symmetrical vertical force profile, consistent with previous models and observations of adult humans, and data for 487 participants (predominantly 11-18 years old) required to walk at a range of speeds at a Science Fair. Work minimization also predicts the discrete walk-run transition familiar for adult humans. In contrast, modeled peak limb mechanical power demands are minimized with an early skew in vertical ground reaction force that increases with speed, and stance durations that decrease steadily with speed across the work minimizing walk-run transition speed. The peak power minimization model successfully predicts a continuous walk-run gait transition that is quantitatively consistent with measurements of younger children (1.1 to 4.7 years) required to locomote at a range of speeds but free to select their own gaits.

P3-24 USHERWOOD, JR*; GRANATOSKY, MC; The Royal Veterinary College, The University of Chicago; *jusherwood@rvc.ac.uk*

Work minimization and foot contact timings in slow upright and inverted quadrupedal gaits

The consequences of footfall phasing in terms of limb work has previously been considered for a range of walking quadrupedal species with models using highly idealized limb forces (Usherwood and Self Davies 2017; also SICB, 2017). In the current study, we extend previous methods to exploit empirical force profiles (see Granatosky, 2016), and relate limb work cost contours to observed phasings across a range of duty factors. We take advantage of measurements on 10 species observed locomoting upside-down, 8 of which are also measured walking upright. This inverted/upright comparison presents different mechanical loading demands, and so contrasting cost surfaces. While the phases used during inverted and upright gaits broadly match low limb work conditions (varying as a function of duty factor), pure work minimization alone is insufficient to account for the selected phases. Upright primates tend to adopt a diagonal footfall sequence, whereas a lateral sequence is usually - very marginally - better. Similarly, a diagonal sequence would be narrowly predicted for many inverted gaits; however, vampire and fruit bats adopt a lateral sequence at very high duty factors, populating a slightly less favourable (though still low-cost) region. The mechanical principles underlying the limb work cost surfaces are discussed, as are non-energetic constraints that may prohibit certain duty factor / limb phase combinations. Granatosky, M.C. (2016). A mechanical analysis of suspensory locomotion in primates and other mammals. PhD thesis, Duke University. Usherwood J.R. and Self Davies Z.T. (2017) Work minimization accounts for footfall phasing in slow quadrupedal gaits. eLife 2017;6:e29495 doi:10.7554/eLife.29495.

P2-85 VACHON, JC*; NEWCOMB, JM; New England College; *jvachon_ug@nec.edu*

The Nudibranch Berghia stephanieae Exhibits Circadian Rhythms of Crawling

Daily patterns of activity in a majority of organisms are influenced by endogenous circadian clocks that entrain to external cues. Recently, the nudibranch *Melibe leonina* has been used for circadian studies due to its relatively simple central nervous system. However, this animal poses challenges to researchers, such as unreliable access to populations for study, and difficulties establishing breeding colonies due to diverse developmental needs of larvae vs adults. The nudibranch *Berghia stephanieae* is readily available in the marine pet trade as a predator of the invasive anemone *Aiptasia pallida*. Since *B. stephanieae* has direct development, successive generations of this nudibranch, as well as sufficient food supplies for all stages of growth, can be conveniently maintained in the laboratory. The goal of this study was to determine if *B. stephanieae* exhibits circadian rhythms of crawling. *B. stephanieae* were visually tracked over a seven-day experiment, with three days of normal light/dark cycles followed by four days of constant darkness. Animals exhibited an overwhelmingly nocturnal pattern of activity. All individuals that remained healthy during the entirety of the experiment also exhibited circadian rhythms of crawling that persisted in constant darkness with an average *tau* value of 21.1 ± 2.5 h (mean ± standard deviation). It was also discovered that *B. stephanieae* are capable of crawling out of the water for extended periods of time (e.g., close to an hour), suggesting possible intertidal adaptations. Based on this evidence, we recommend *B. stephanieae* as an organism for future studies of circadian rhythms at the genetic and neurological level.

P3-20 VALENCIA, M/M*; KAWANO, S/M; Long Beach State Univ.; *MrMilesValencia@Gmail.com*

Comparative kinematics of the forelimb during terrestrial locomotion in semi-aquatic versus terrestrial salamanders

Locomotion is affected by the physical features of the environment that may affect loads applied to the bones, such as buoyancy in water versus greater effects gravity on land. Salamanders live in aquatic and terrestrial habitats and must accommodate the contrasting demands of both environments, but do those that primarily live underwater exhibit decreased locomotor performance on land? To evaluate differences in salamander forelimb function, we compared how semi-aquatic adult Spanish ribbed newts (*Pleurodeles waltl*) and predominantly terrestrial adult tiger salamanders (*Ambystoma tigrinum*) overcome a similar challenge: terrestrial locomotion. We quantified the 3D kinematics of the forelimbs on level ground in *P. waltl* and then compared these data to those published on *A. tigrinum*. Preliminary analyses suggested that *P. waltl* and *A. tigrinum* exhibited similarities about the elbow and wrist, with a few distinct differences. The kinematic profile of the elbow in *P. waltl* generally followed the same pattern as *A. tigrinum*, except with slightly more extension throughout stance. The timing of maximum flexion about the wrist in *P. waltl* occurred later in stance compared to *A. tigrinum*, and the duty factor of *P. waltl* was lower than *A. tigrinum*. These preliminary results suggested that the degree of terrestriality in salamanders may not affect these kinematic variables during terrestrial locomotion, but ongoing analyses of locomotor function along the entire forelimb will provide a more comprehensive evaluation of whether semi-aquatic salamanders employ different strategies than terrestrial salamanders for moving on land. Findings from this research may provide new insights into the many-to-mapping of forelimb function for terrestrial locomotion.

33-3 VALLEJO-PAREJA, MC*; DAZA, JD; MAISANO, JA; RANDLE, C; THIES, ML; University of Florida, Gainesville, Sam Houston State University, Huntsville, University of Texas, Austin; *maria.vallejo@ufl.edu*

A characterization of miniaturized lizard skull traits based on a meta-analysis

Squamates (lizards, snakes and amphisbaenians) that are derived from large- or medium-sized ancestors, and have acquired skull lengths that are less than or equal to 15 mm, are considered 'miniaturized.' Morphological characteristics associated with miniaturization have been identified in at least 21 of the 68 recognized squamate families, however, some of these characteristics have been studied only in a few species and the available information does not adequately represent the diversity within Squamata. Here, we evaluate all previously proposed skull characteristics associated with miniaturization and explore a published morphological dataset of 437 skull characteristics for 204 squamates to identify additional characteristics. The meta-analysis allows us to compile 21 traits associated with miniaturization. We find that phylogenetic history and skull design influence the way in which species become miniaturized, therefore there are not universal features that can be found in all miniaturized species. We corroborate general traits that are found in the majority of miniaturized squamates including: reduction of the post-temporal fenestra; reduction of the supratemporal fenestra; elongation of the skull; shifting of the occipital condyle to the posterior-most margin of the skull; and reduction of the paraoccipital process. We identified additional characteristics including: reduction in the number of postdentary bones, not only in fossorial species; loss of the splenial bone; and reduction in the number of dentary teeth. This meta-analysis indicates that jaw morphology is especially affected by miniaturization, therefore variation in this structure should be explored further in small reptiles, including living and fossil groups.

S4-8 VAN CASTEREN, Adam*; CROFTS, Stephanie; Washington University in Saint Louis, University of Illinois at Urbana-Champaign; *adam.vancasteren@gmail.com*

Biomaterials to structure: exploring the interplay between tooth materials, structure, and function

One of the main functions of teeth is to induce fracture, reducing food items to an ingestible size and increase the surface area of food to promote more efficient enzymatic digestion. A lifetime of regular use subjects teeth to a great deal of potential damage, via contact with foods, with themselves, and other external contaminants of the oral cavity. Enamel, often the main contact tissues of teeth is under almost constant threat of mechanical damage. This highly mineralized biological composite exhibits a structural hierarchy of organization, thus allowing enamel to be optimized for seemingly competing selective pressures. Its high mineral content bestows the material with high hardness and stiffness whilst the remnant proteins and structural arrangement provide the material with a surprising degree of toughness protecting against fracture. In addition to changes in material structure, different tooth morphologies also serve to control the damage dealt by everyday use. Patterns of tooth specializations associated with different diets have been well documented across taxa, mammalian and otherwise, and the functional significance of different tooth shapes remains a topic of interest. Here we present recent methodological advances and results that are allowing researchers a deeper understanding of the behavior of enamel and teeth. Tooth function is a complex set of interactions between tooth biomaterials, tooth-food interactions, and overall tooth structure. Such a viewpoint allows a greater understanding of the selection pressures that are shaping dental optimizations at many scales.

17-8 VAN MEER, NMME*; WELLER, HI; MANAFZADEH, AR; KACZMAREK, EB; SCOTT, B; GUSSEKLOO, SWS; WILGA, CD; BRAINERD, EL; CAMP, AL; Wageningen UR, Brown U, U Illinois Urbana-Champaign, U Alaska Anchorage, U Liverpool; *noralymmevanmeer@gmail.com*

Food capture, transport and swallowing in white-spotted bamboo sharks (Chiloscyllium plagiosum)

After capturing food, there are at least two equally important steps in feeding: food transport and food swallowing. Previous studies in aquatic vertebrates have found that water currents transport food from the mouth towards the esophagus (i.e. the hydrodynamic tongue), and that oral cavity expansion generates this flow. They were, however, limited by technology and unable to visualize the food position within the animal. We used X-ray Reconstruction of Moving Morphology (XROMM) to track the pathway of food in 3D in three white-spotted bamboo sharks, allowing us to measure food and cartilage movement during transport and swallowing. Gape width, ceratohyal and pectoral girdle elevation, and food displacement were analyzed for each feeding bout. We found that food moves with a ratchet-like motion once inside the oropharynx. Caudally-directed motion of the food occurs during hyoid elevation, and the food appears to be stationary during ceratohyal depression, perhaps held in place by branchial basket compression. Hyoid elevation compresses the oral cavity, so the shark likely generates water currents through the oropharynx to push food backwards. Food is pushed into the esophagus by hydrodynamics as well. Despite a smaller range of motion of the ceratohyal and pectoral girdle, food velocity is higher. This indicates that branchial basket compression might push food into the esophagus. Hence, water currents generated by cranial cartilages and branchial basket compression are key elements in moving food towards and into the esophagus. These actions are as important as food capture for animal survival.

59-4 VAN NEST, BN*; DALY, KC; WILLIS, MA; Case Western Reserve University, West Virginia University; *bnv11@case.edu*

Blocking an Olfactory Corollary Discharge Circuit Impairs Odor Plume Tracking in Manduca sexta

The nervous system of a behaving animal must be able to distinguish sensory signals arising from its own movement from sensory signals arising from the environment. This is accomplished by modulating sensory input via a corollary discharge circuit (CDC), which relays information from motor networks to the relevant sensory circuits. Visual-, auditory-, and proprioceptor-motor CDCs have previously been described in many systems, but until recently, olfactory-motor CDCs were unknown. In moths, a pair of mesothoracic-deutocerebral histaminergic neurons (MDHns) project from flight sensorimotor centers in the mesothoracic neuromere to the antennal lobes (ALs). We recently demonstrated that MDHn spiking activity is correlated with wingbeat motor output, and application of histamine to the MDHns sharpens AL projection neuron entrainment to odor stimuli. Likewise, application of a histamine H2 receptor antagonist reduces projection neuron entrainment and inhibits odor detection and discrimination. Here we test the effects of blocking the MDHn circuit on a moth's ability to track an odor plume in a wind tunnel. Cimetidine (an H2 receptor antagonist) or saline vehicle was injected bilaterally into the ALs of tobacco hornworm moth (*Manduca sexta*) males. Cimetidine-injected moths successfully tracked sex pheromone plumes, but their flight dynamics were significantly different than controls: cimetidine-injected moths flew slower, had smaller course angles, and had longer inter-turn durations than controls. These results are consistent with the observed effects of H2 receptor antagonists on reduced preparations.

129-4 VAN WASSENBERGH, S; Muséum National D'Histoire Naturelle, Paris; *svanwassenbergh@mnhn.fr*

Three-dimensional patterns of water flow in a cross-step model of a filter feeding fish

Recent studies on how fish filter food particles out of the water have identified the importance of vortices that form ‘hydrocyclonic nets' that repel zooplankton away from the filter surface formed by the gill rakers, and concentrates them within the buccal cavity. Furthermore, physical models in flow tanks showed that similar vortices keep part of the branchial sieve void of adhering particles, and thus avoid clogging. One of these models, a simplified representation of the morphology of the ram filter feeding paddlefish, is the cross-step model by Sanderson and co-workers published in Nature Communications in 2016. Apart from flow visualization with dye and local flow magnitude measurements, the hydrodynamics of this cross-step model remain unclear, which limits our insight in the links between the filter's geometry, flow patterns and filtration performance. I quantified the 3D-hydrodynamics of the cross-step model with ‘ribs' at 90° and solved particle tracks using the computational fluid dynamics software ANSYS Fluent. The model shows the importance of the resistance by the gill rakers (represented by a nylon mesh in the physical model, and a ‘porous media model' in the computational model) to establish the vortices. As predicted, the zone on the filter where no particles were retained showed a low pressure and a strongly shearing flow. The vortices consistently showed a helical pattern with a ventral-to-dorsal flow direction. Calculation of the paths of neutrally buoyant spherical particles of a range of sizes did not show the repelling action of the vortex to cause separation from the flow. Therefore, the current computational model predicts that filtration by this model is occurring by cross-flow or dead-end filtration the level of the gill rakers instead of more medial inside the mouth cavity.

94-3 VANDER LINDEN, AR*; DUMONT, ER; Univ. of Massachusetts Amherst, Univ. of California, Merced; *avanderlinde@umass.edu*

Combat Behavior Predicts Morphology of Cervical Vertebrae in Male Ruminant Mammals

Bovids (cattle, sheep, goats, antelope) and cervids (deer) belong to the clade Ruminantia and possess distinct and varied cranial appendages in the form of horns and antlers. These appendages are used as sexual display organs and as weapons in intraspecific combat between males for access to mates. Intraspecific combat in these species takes many forms, including head-on collisions (ramming); attempting to stab an opponent's head or body with horn tips (stabbing); rearing and clashing downwards with horns (fencing); or interlocking antlers or horns while vigorously pushing and twisting (wrestling). Some aspects of horn morphology, horn and antler material properties, and skull morphology have been linked to combat behaviors in bovid and cervid species, but the role of the cervical vertebrae and supported neck musculature in opposing the forces generated during fighting has not been explored. We quantified biomechanically relevant linear measurements of the cervical vertebrae (C1 - C7) of 49 ruminant species and regressed them on sex-specific body mass averages to obtain size-standardized measure of vertebral morphology. We then used phylogenetic ANOVA to assess differences in morphology among species that display primarily ramming, stabbing, fencing, and wrestling combat styles. In males, we found that wrestlers had significantly longer centra than rammers, stabbers, or fencers, while rammers had significantly wider centra and prezygapophyses. However, we found no significant relationship between vertebral measurements and fighting style in females. These results suggest an adaptive role for the cervical vertebrae in resisting forces generated by male intraspecific combat in ruminant mammals.

P2-115 VANGORDER-BRAID, JT*; SIRMAN, AE; GHIMIRE, A; KITTILSON, J; HEIDINGER, BJ; North Dakota State University; *jennifer.vangorderbr@ndsu.edu*

Does Chronic Stress Exposure Influence TERT Expression and Telomere Loss in Developing House Sparrow Nestlings (Passer domesticus)?

Early life telomeres, protective caps at the end of eukaryotic chromosomes, are predictive of lifespan. Exposure to chronic stress during development can have long-term consequences on individual fitness and longevity. Chronic stress can detrimentally impact an organism through shortening of telomeres, which limits cellular lifespan. However, telomerase, an enzyme that lengthens telomeres, has been shown to upregulate in times of chronic stress in adult mice. Telomerase is made up of two subunits: a reverse transcriptase protein (TERT) and the RNA template (TERC). To better understand the impacts of chronic stress during development, we measured TERT gene expression in early life of house sparrow nestlings in response to chronic stress. Nestlings were randomly assigned a stress or control treatment group, and the stress treatment group received handling in a cloth bag for 30 minutes, daily, from 3 to 10 days post-hatch. At 10 days post-hatch, tissue samples were collected for TERT expression and telomere analysis. We predicted that experimentally stressed nestlings would have higher TERT gene expression than control nestlings. Variation in TERT expression could have important effects on telomeres and contribute to individual differences in resilience to stress exposure.

P1-1 VARNER, J; CONNORS, PK*; BROWN, JS; DIZNEY, L; DUGGAN, JM; ERB, LP; FLAHERTY, EA; HANSON, J; LANIER, HC; YAHNKE, CJ; Colorado Mesa Univ., Grand Junction, Univ. of Utah, Salt Lake City, Moffitt Cancer Center, Tampa, Univ. of Portland, Portland, California State Univ. Monterey Bay, Seaside, Warren Wilson College, Asheville, Purdue Univ., West Lafayette, Columbus State Univ., Columbus, Univ. of Oklahoma, Norman, Univ. of Wisconsin Stevens Point, Stevens Point; *patrice.kurnath@utah.edu*

Squirreling Around for Science: Incorporating Sciurid Behavioral Research into Undergraduate Curriculum

Course-based Undergraduate Research Experiences (CUREs) have been proposed as a way to engage undergraduates in authentic research and to teach core concepts using inquiry-based activities. Compared to traditional labs, CUREs may better enhance intellectual independence and critical thinking because scientific outcomes are unknown. Here, we present preliminary outcomes of a CURE investigating tradeoffs between foraging and vigilance behaviors in squirrels. We developed and piloted a simple, focal-animal observation protocol that works across habitats and species. Students submitted data via Google and then analyzed the nationally aggregated dataset to test their own hypotheses. Last year, we implemented this activity across an array of colleges and courses (upper/lower division, majors/non-majors). Preliminary assessments suggest that students gained confidence in their research abilities and became more interested in science career paths after participation. Additionally, several students sought out independent research opportunities to extend their results (e.g., giving up density and/or camera traps). Our results suggest that participation in course-based research projects enhances not only students' research skills but also their confidence in conducting research, which has important implications for their future as scientists and for increased retention/persistence of students from under-represented groups.

P2-206 VARNEY, RM*; SPEISER, DI; KOCOT, KM; Univ. of Alabama, Univ. of South Carolina; *rvarney@crimson.ua.edu*

The Genome of the Chiton Acanthopleura granulata: A Model System for Studying Molluscan Biomineralization

Chitons (Polyplacophora) are a group of marine molluscs with remarkable biomineralization capabilities. Chitons graze on algae by scraping rocks with a toothed organ called the radula. Feeding is facilitated by teeth coated with iron (magnetite), offering abrasion resistance without compromising flexibility. Rather than a single shell, chitons bear eight valves composed of aragonite. Embedded within the valves are sensory organs known as aesthetes. In *Acanthopleura granulata*, the fuzzy chiton, some aesthetes are modified into lensed eyes that provide spatial vision. To better understand the mechanisms of biomineralization in chitons, we sequenced a draft genome of *Acanthopleura granulata*. A single individual was collected from the Florida Keys and DNA was extracted from foot (muscle) tissue. Sequencing was performed using a hybrid approach with data from the Oxford Nanopore and Illumina HiSeq X platforms, assembled in MaSuRCA. N50, annotation with MAKER, and assessment of completeness with BUSCO indicate that this cost-effective hybrid assembly approach is suitable for producing high-quality draft genomics for integrative biological research. Moving forward, Bionano SAPHYR optical mapping will be employed to further improve assembly quality. This resource will facilitate comparative studies of gene expression in the developing chiton radula to shed light on the genomic basis of their remarkable iron biomineralization. Further, this genome will join fewer than 10 sequenced molluscan genomes and is the first genome from the clade Aculifera (Polyplacophora and Aplacophora, sister group to all other molluscs).

106-4 VAUGHT, RC*; BONDURIANSKY, R; DOWLING, DK; School of Biological Sciences, Monash University, Clayton, VIC 3800, Australia, UNSW Australia, Evolution and Ecology Research Centre and School of Biological, Earth, and Environmental Science, Sydney, NSW 2052, Australia; *rebecca.vaught@monash.edu*

Mitochondrial and X chromosome (Mito-X) Genomic Interactions and Implications for the Evolution of Sex Differences

In metazoans, mitochondria follow a strict mode of maternal inheritance. In theory, maternal inheritance will render selection ineffective in removing mitochondrial DNA mutations that are explicitly male-harming. Similarly, in species with XY sex determination, the X chromosome spends two-thirds of its evolutionary existence inside of females (since females are XX and males XY), which theory suggests could also lead to the accumulation of sexually-antagonistic fitness variation. Furthermore, this female-bias in the inheritance of the X chromosome increases the rate of co-transmission between allelic combinations on the X chromosome and mitochondrial genome to 67% (versus 50% for autosomal-mitochondrial allelic combinations), which should facilitate female-specific co-adaptation between mitochondrial and nuclear genomes, but potentially at the expense of male performance. Here, we test this hypothesis. We first created genetic strains of the fruit fly, *Drosophila melanogaster*, which possess one of five mtDNA haplotypes and five X chromosome genotypes, in all possible combinations, in an otherwise standardized autosomal background. We used these strains to explore whether genetic combinations of mtDNA haplotype and X chromosome exert sex-specific, potentially sexually-antagonistic effects on longevity. Our work helps elucidate the contribution of sexual asymmetry in the inheritance of particular genomic regions to the evolution of sex differences in life-histories.

17-6 VAZ, D/F, B*; HILTON, E/J; Virginia Institute of Marine Science, College of William and Mary; *dbistonvaz@vims.edu*
Ontogeny of the Plainfin Midshipmen, Porichthys notatus (Batrachoididae: Batrachoidiformes)
Batrachoidiformes is a monophyletic group of mostly benthic, ambush-predatory fishes. Species of the genus *Porichthys*, the midshipmen, are unique in this order for having photophores and being relatively pelagic. Despite inhabiting deeper habitats than other Toadfishes, species of *Porichthys* build nests in intertidal rocky habitats, similar to other Batrachoidiformes. Previous ontogenetic studies have described only the external larval morphology of few species of Batrachoidiformes, and data on the skeleton and soft tissues are lacking. Ontogenetic data are important for understanding homology and the phylogenetic relationships among taxa. An ontogenetic series of the early life stages of Plainfin Midshipmen, *P. notatus* (5 to 28 mm TL), was collected during the summers of 2017 and 2018, and skeletal ontogeny was investigated using cleared-and-stained specimens. Changes in the neural and muscular system were examined by staining whole specimens with Phophomolybdic Acid and CT-scanning them at resolution of 5.7 microns. The development of the vertebral column occurs in an anterior to posterior direction, as in other percomorph fishes. When larvae hatch from the corion, the basidorsal elements of the first vertebrae are already present. The third dorsal-fin spine, previously proposed to be absent in *Porichthys*, was observed in early stages (7 mm TL), but is reabsorbed before larvae become free swimming (25 mm TL). The brain displays allometric growth, having an optic lobe that is almost one-half of the length of the brain in early stages (5-8 mm TL); it becomes less than one-quarter of brain length in free-swimming juveniles (>30 mm TL). Individual portions of the *adductor mandibulae* complex are completely distinct in all observed stages.

140-3 VEGA, CM*; CHADWELL, B; ASHLEY-ROSS, MA; Wake Forest University, Idaho College of Osteopathic Medicine; *vegacm11@wfu.edu*
Turtling the salamander: the role of lateral undulation in sprawling locomotion
Lateral undulation of the vertebral column is an important characteristic of sprawling postured tetrapod locomotion. The goal of this study was to determine the role of the lateral movement of the trunk vertebrae in terrestrial locomotion of tiger salamanders (*Ambystoma tigrinum*). This was done by artificially limiting trunk flexibility by attaching a 2-piece "shell" around the body between the pectoral and pelvic girdles. Adult tiger salamanders (n =3, SVL = 9 cm-14.5 cm) walked on a 1 m trackway under three different conditions: no shell, flexible shell (tygon tubing), and rigid shell (PVC tubing). Trials were filmed in a single, dorsal view using a Kodak Playsport camera (30 fps). Kinematic markers were located on the wrist, elbow, and shoulder joints of the forelimb. A custom-written MATLAB program was used to track the midline and the forelimb movements of the salamanders and analyze kinematic variables. Average and maximum curvatures over (1) the entire midline and (2) restricted trunk/tail regions were compared over multiple strides. Curvature over the whole midline was higher in the flexible and rigid shell treatments compared to the control. This trend seems to be driven by an increase in curvature in the tail region, perhaps to compensate for the shells. Curvature in the trunk region was lower for the rigid shell treatment compared to the flexible shell and control. The reduction of lateral flexion results in one region of the body results in compensatory movements in other regions.

P3-41 VEGA, K.*; CLARK, C.J.; California State University, San Bernardino, University of California, Riverside; *vegak303@coyote.csusb.edu*
Limits to Top Speed in Hummingbirds
Vertebrates such as hummingbirds can fly at high speeds. The limit that prevents hummingbirds from flying faster is the amount of forward-direct thrust. Thrust is affected by the kinematics of flight at high speed, such as the maximum wingtip velocity during the wing beat. The wingtip velocity hypothesis states that top speed is limited by purely kinematic factors at higher flight velocities. The muscle power hypothesis states that the size of the pectoralis muscle is a determining factor of the top speed a bird can reach. We tested 25 hummingbirds from 4 species (that vary in body size, wing length, and muscle size) to determine whether muscle size, body size, or wing length is correlated with limiting thrust. Top speed was determined by placing birds in a wind tunnel starting at 9.5 ms^{-1} and increased in increments of 0.03 ms^{-1} every 10 seconds. A high-speed camera was used to capture wing kinematics at 9.5, 11, and 13 ms^{-1}. In a separate assay, we measured the maximum load lifting capacity in still air. Top speed increased as calculated wingtip velocity increased across species. Hummingbirds that showed an increase in stroke amplitude at the highest airspeeds. Top speed showed a negative correlation with total body weight lifted during the load lifting exercises. This could indicate that wing kinematics alone are responsible for the amount of thrust produced and limits how fast a hummingbird can fly during forward flight.

109-6 VELAZQUEZ, AM; PALUSO, JM; BOUCHER, TJ; BRANNOCH, SJ; SVENSON, GJ; MARTIN, JP*; Colby College, Cleveland Museum of Natural History; *jpmartin@colby.edu*
Comparative morphology of motor control in praying mantises
Adaptations of control systems (motor control circuits in the brain) and effectors (limbs and body segments) are both required to suit an animal's movements to its environment. Praying mantises (Mantodea) offer a unique opportunity to explore these relationships. While all mantises are predators that use their forelegs to grasp prey, diverse species are specialized for movement on different substrates (grasses, bark, leaves, etc.), hunting strategies (ambush or pursuit), or mode of movement (climbing or running). We report comparative morphological studies on the central complex (CX) of the insect brain, which controls and directs movement, and the limbs and body segments of mantises. Using confocal microscopy and micro-CT imaging, we created 3D reconstructions of the major neuropils of the central complex (including the protocerebral bridge, fan-shaped body, ellipsoid body, and lateral accessory lobes). The morphology and relative volumes of these regions cluster into three subgroups of species: 1) highly cryptic, ambush specialists, 2) pursuit specialists, and 3) generalists that both pursue and ambush prey. A parallel analysis of the structure of the forelegs from two-dimensional images and three-dimensional scans revealed that only species with special resemblance to sticks and grasses deviate significantly from the average morphology. These results begin to describe a potentially rich example of the interaction between evolutionary history, the control of movement, and the physical form of an animal.

75-5 VENABLE, CP*; LANGKILDE, TL; The Pennsylvania State University; *cpv111@psu.edu*

Eating toxic invasive ants turns lizards off eating native ants

Invasive species can act as prey, sometimes having detrimental effects on native predators that consume them. Some native species can avoid eating noxious invasive prey. In some cases, these invaders are similar to palatable native species. If exposure to noxious invasive prey alters native predator consumption of similar native prey, this could alter diets of native predators and have important ecological consequences. The red imported fire ant, *Solenopsis invicta* acts as an invasive prey source within the southern range of the eastern fence lizard, *Sceloporus undulatus*. Juvenile fence lizard diets are comprised largely of ants, but eating fire ants can prove lethal, however, lizards can quickly learn to avoid eating them. We tested whether prior exposure to (and subsequent avoidance of) invasive fire ants will reduce the subsequent consumption of a palatable native ant species. We allowed juvenile lizards to eat either invasive fire ants or palatable native ants for 5 days (training period) and then tested their subsequent consumption of the native ant over the next 5 days. We found that lizards that ate fire ants during their training period were less likely to subsequently consume palatable native ants. These results suggest that eating invasive prey can lead native species to avoid similar palatable native species which, in cases like our where this may form the basis of their diet, could have important effects that may cascade throughout the ecosystem.

P2-143 VENKATESWARAN, V*; KUMBLE, LK; BORGES, RM; Indian Institute of Science; *vvignesh@iisc.ac.in*

Resource Dispersion influences Dispersal Evolution of Highly Insulated Insect Communities

Communities in which species are obligately associated with a single host plant are ideal to test adaptive responses of community traits to selection since such communities are often highly insulated. Fig species provide oviposition resources to co-evolved fig-wasp communities. Dispersing fig-wasp communities move from one host plant to another for oviposition. We compared the spatial dispersion of two fig species and the dispersal capacities of their multitrophic wasp communities. Dispersal capacities were assessed by measuring vital dispersal correlates, namely tethered flight durations, somatic lipid contents and resting metabolic rates. We suggest that dispersal-trait distributions of congeneric wasp species across the communities are an adaptive response to host plant dispersion. Larger dispersal capacities of the entire multitrophic community are related to more widely dispersed resources. Our results provide evidence and a novel perspective for understanding the potential role of adaptation in whole-community dispersal-trait distributions.

P3-146 VERHAGEN, I *; LAINE, V N; MATEMAN, A C; PIJL, A; KAMPHUIS, W; GIENAPP, P; VAN OERS, K; VISSER, M E; NIOO-KNAW, NIN-KNAW; *i.verhagen@nioo.knaw.nl*

Assessing individual gene expression patterns in the reproductive axis in relation to timing of reproduction in the great tit (Parus major)

The causation of variation in avian timing of reproduction is ultimately rooted in its underlying physiology, as, after transduction and integration of cues, reproductive timing results from a cascade of neuro-endocrine processes. Current knowledge on the physiology underlying avian breeding time is still limited despite its importance as a key trait involved in how species adapt to climate change. This study assesses whether (individual) differences in egg-laying date can be explained by differences in candidate gene expression in a number of tissues and if so, whether these differences occur in the upstream (i.e. hypothalamus), or the downstream (ovary and liver) part of the neuroendocrine system. We used 72 female great tits from lines artificially selected for early and late laying, which were subjected to two contrasting temperature environments in climate controlled aviaries and sacrificed at three time points throughout the breeding season. For each organ for a set of candidate genes, known to be important or potentially important mediators of reproductive biology, individual gene expression levels were assessed using qPCR methods. Instead of analyzing candidate genes separately, we first conducted a Principal Component Analyses (PCA) per organ and subsequently analysed whether gene expression patterns differed in relation to egg-laying date, time point of sacrifice, and temperature treatment. A better understanding of individual gene expression patterns can contribute greatly to understanding the molecular evolutionary processes in natural populations, and the adaptive potential of species to adapt to environmental change.

22-4 VERNASCO, BJ*; HORTON, BM; RYDER, TB; MOORE, IT; Virginia Tech, Millersville University, Smithsonian Institution; *bjv4@vt.edu*

Reduced cooperative behavior as a cost of high testosterone in male wire-tailed manakins

The seasonal regulation and social responsiveness of androgens have been modeled by the Challenge Hypothesis, and one of the primary suggestions is that maintaining high levels of androgens can be costly. Indeed, many studies have suggested that high levels of androgens can reduce parental care, be immunosuppressive, and increase mortality rates. However, one potential cost of testosterone that has yet to be considered is that of reduced cooperative behavior. In many species, cooperation is key to reproduction and/or survival. Male wire-tailed manakins (*Pipra filicauda*), for example, perform coordinated male-male courtship displays, and males engage in long-term display partnerships with other males. Individual variation in cooperative behavior has fitness consequences, as more cooperative individuals have higher reproductive success. Here, we use both observational and experimental approaches to determine whether and how androgens mediate variation in cooperative behavior among male wire-tailed manakins. Observationally, we measured the relationship among display behavior, cooperative behavior, and circulating androgen levels. Experimentally, we measured display and cooperative behaviors before and after administering a testosterone implant. Our observational results show that individuals with higher levels of androgens engage in relatively fewer cooperative displays. Similarly, experimentally increased testosterone levels reduced the proportion of an individual's displays that were cooperative. Our findings suggest that androgens mediate variation in male cooperative display behavior and that reduced cooperative behavior is a potential cost of high testosterone.

P2-153 VIMMERSTEDT, JC*; YOUNGBLOOD, JP; ANGILLETTA, JR, MJ; QUINLAN, MC; LEE, AH; VANDENBROOKS, JM; Midwestern University, Arizona State University; *jvimmerstedt23@midwestern.edu*

Testing the OCLTT hypothesis in quail embryos by manipulating thyroid hormone

Currently, the primary mechanism establishing upper thermal limits is unknown. The classic protein denaturation hypothesis remains unlikely as most proteins denature at temperatures higher than the critical thermal limits for organisms. Alternatively, the oxygen and capacity-limited thermal tolerance (OCLTT) hypothesis predicts that increasing temperatures cause a mismatch between oxygen supply and demand, forcing the animal to transition to anaerobic metabolism, which fails to meet energetic demand leading to organismal death. Most support for the OCLTT hypothesis has come from aquatic animals with relatively little support in terrestrial animals. Yet in the embryonic stage, terrestrial animals may be more susceptible to oxygen limitation due to underdeveloped cardio-respiratory systems and living in an aquatic medium. We tested this hypothesis in Japanese quail (*Coturnix coturnix*) embryos by attempting to artificially increase basal metabolic rate with treatment of thyroid hormone (T3). Halfway through development, T3 dissolved in DMSO was injected into the yolk of half of the eggs, while the other half received vehicle only. Embryos were then exposed to 48.0°C for one hour to measure survivorship. If the OCLTT hypothesis were correct, the embryos injected with T3 should show reduced survivorship at high temperatures due to increased oxygen demand. In fact, survivorship in the T3 injected group was one quarter of that in the control group suggesting that oxygen availability may be limiting thermal tolerance. However, the relationship between metabolic rate and survivorship was weak indicating a possible secondary effect of T3 independent of metabolic rate. Therefore, further studies are necessary to elucidate the direct mechanisms behind this effect.

49-2 VINDIOLA, BG*; DAVIS, TJ; Florida Atlantic University; *bvillegasvin2013@fau.edu*

Assessing and Comparing Nest to Surf Mortality of Florida's East and West Coast Loggerhead Sea Turtle Hatchlings

During the crawl from the nest to the surf, sea turtle hatchlings face many threats, both natural and anthropogenic, which can affect their ability to successfully locate the surf zone. As a species managed for recovery, collections of accurate demographic data are critical. Currently, data gaps exist in the current hatchling production estimates; they omit hatchling mortality occurring between emergences from the nest and entering the surf. Consequently, hatchling recruitment to the oceanic life stages may be overestimated. In this study, we identify nest-to-surf mortality and possible threats to hatchlings on Florida's east and west coast beaches. We compare how threats impact survival of hatchlings and identify how threats differ between coasts and across years (2017-2018). Predators identified include ghost crabs, foxes, raccoons, night herons, and fire ants. Anthropogenic impediments such as sky glow and barriers, varied by site. By identifying the relative magnitudes of threats and threats specific to particular nesting locations, we are able improve hatchling recruitment estimates and inform local wildlife managers of site-specific risks, so that they can use the most appropriate mitigation approaches to reduce the decline of local populations.

P3-170 VIRGIN, EE*; FRENCH, SS; Utah State University; *emilyevirgin@gmail.com*

Effect of immune challenge on metabolism and oxidative capacity in the Side-blotched lizard (Uta stansburiana) across reproductive stages

Activation of the innate immune system is costly and can result in an energetic deficit for other physiological processes, such as reproduction. Both immunity and reproduction can induce a suite of physiological changes, including an increase in metabolic rate. A byproduct of metabolism is the production of reactive oxygen species (ROS), which have the potential to cause cellular damage and early senescence. It is unclear how competition between the immune and reproductive systems influence metabolic rate, and how simultaneous investment between reproduction and immunity relates to metabolic and oxidative costs in females. Here, we immune challenged 77 wild-caught female side-blotched lizards (*Uta stansburiana*) varying in reproductive stage with lipopolysaccharide (LPS), a non-pathogenic mitogen that induces an immune response, and measured the effects on standard metabolic rate, innate immune function (BKA), and oxidative capacity (both antioxidants and reactive oxygen species). Understanding the metabolic and oxidative costs of immunity and how they may vary depending on reproductive status (and the tradeoffs therein) is crucial to understanding how life history traits evolve in animal populations.

P1-286 VITEK, NS*; MORSE, PE; STRAIT, SG; BOYER, DM; BLOCH, JI; University of Florida, Gainesville, FL nvitek@ufl.edu, Duke University, Durham, NC, Marshall University, Huntington, WV, Florida Museum of Natural History, Gainesville FL; *nvitek@ufl.edu*

Changes in relative molar size in the small-bodied mammal Macrocranion across the Paleocene-Eocene Thermal Maximum follow predictions of nutritional deficit

Variation in relative molar crown area (RCA) is a promising phenotype in which to measure mammalian response to climate change because of its links to diet and nutritional deficit in modern species. A relevant interval in which to study these responses is the Paleocene-Eocene Thermal Maximum (PETM) ~56 Ma. It is associated with a shift towards warmer mean annual temperatures (MAT) by ~5-8 °C for ~175 ky, followed by a recovery to pre-PETM MAT. Changes in RCA in response to these climatic shifts should follow predictions of the inhibitory cascade model (ICM). However, much of the PETM mammalian fossil record consists of isolated teeth instead of the complete molar rows for which the ICM was intended. To test the possibility of environmentally-linked change in RCA, we first asked if we could reconstruct RCA from averages of isolated molars. Using simulations from modern populations, we demonstrate that this approach accurately reflects molar-row RCA. Next, we asked whether RCA changed through the PETM, and, if it did, whether changes in RCA through the PETM follow expectations of the ICM. We measured RCA from isolated M_{1-3} of the small-bodied (~24 g), insectivorous *Macrocranion junnei*. RCA changes across the PETM in proportions consistent with the ICM. Macrocranion has smaller M_{2-3} during the late and post-PETM at most. The timing and direction of change is consistent with nutritional deficit associated with turnover in the surrounding flora and associated insect fauna at the end of the PETM.

S5-8 VITOUSEK, Maren N*; TAFF, Conor C; ZIMMER, Cedric; ARDIA, Daniel R; Cornell University, Franklin and Marshall College; *mnv6@cornell.edu*

Stress and success: The role of variation in the efficacy of negative feedback in the glucocorticoid stress response

Effectively coping with stressors may involve not only mounting a vigorous stress response, but efficiently and effectively terminating this response to return to normal behaviors and physiological processes. Yet while the phenotypic and fitness effects of mounting a strong hormonal stress response have been widely studied, much less is known about whether individual variation in the ability to terminate the stress response through negative feedback influences performance and fitness. Recent findings in free-living tree swallows *(Tachycineta bicolor)* have begun to elucidate the role of individual variation in negative feedback in predicting both resilience to and recovery from challenges. The efficacy of negative feedback is typically measured through circulating glucocorticoid levels, but the downstream effects of varying GC levels are mediated through receptor binding. Ongoing experiments are also beginning to illuminate how receptor expression, and potential epigenetic mediators of receptor expression, may influence individual variation in negative feedback, and its fitness effects. Overall, our results suggest that the ability to rapidly terminate the stress response through negative feedback may be an important determinant of why some individuals, and some populations, cope with challenges more effectively than others.

62-1 VOMPE, A/D*; EISENLORD, M/E; WINNINGHAM, M; HARVELL, C/D; Cornell University; *adv26@cornell.edu*

Ecology and transmission mechanisms of Labyrinthula zosterae in beds of Zostera marina seagrass

Seagrasses inhabit only a small fraction of the world ocean; yet, they provide important ecosystem services such as juvenile salmon nurseries and atmospheric carbon sequestration. Globally, seagrass beds are susceptible to Seagrass Wasting Disease (SWD). Eelgrass Wasting Disease (EGWD) is the variant of SWD occurring in eelgrass (*Zostera marina*). Entire beds of eelgrass can be infected and destroyed. EGWD is caused by the amoebozoan slime mold *Labyrinthula zosterae* (LZ). The transmission of LZ in field as well as the functional morphology of LZ colonies have not been extensively studied. In our study, field experiments at different sites in 2017 and 2018 showed that sentinel blades deployed inside and outside eelgrass beds both develop new infections, suggesting the likely transmission of LZ through the water column. Infection prevalence, severity, and disease lesion number were not different between inside and outside eelgrass bed treatments after two weeks of incubation in the field and were significantly higher than in infection baseline control plants. Colony morphology was also studied via phase contrast and confocal microscopy. Analysis of collected environmental samples (including water, sediment, associated algae, and epibiont) would provide finer resolution on the location of LZ *in situ* and is currently being carried out.

P3-14 VYAS, P*; PRAKASH, M; Stanford University; *vpranav@stanford.edu*

Dynamics of Placozoa cellular reaggregation: Self-organization of tissue architectures via assembly/disassembly of Trichoplax adhaerens

Placozoans are one of the earliest diverging metazoans with a simple body plan. They have six cell types arranged in a three-layered sheet morphology without ECM. Their extreme diversity of shape and tissue plasticity are properties arising from local interactions between cells, whose emergence can be probed due to the simplicity of the system. The animal reproduces asexually through fission induced by uncoordinated flocking of cilia, but also sometimes buds spherical pelagic swarmer balls from its dorsal surface. These balls have been reported to undergo a topological transition during which the ventral epithelium enclosing an inner cavity is exposed to the outer environment. The dorsal and ventral surfaces have characteristic functions illustrated by unique distinguishable cell arrangements. We aim to better understand the role of self-organization processes that lead to these simple tissue architectures. A shear-based dissociation assay allows us to obtain tissue fragments with tens to hundreds of cells. These fragments show motility and reaggregation followed by slow rearrangements of cells to gain defined arrangements. This process provides room for *in vitro* formation of swarmer balls along with other artificial morphologies with multiple cavities. The assay also allows us to obtain animals with tuned sizes which show a transition from a more rounded to a flatter morphology with increase in size. Comparative study of this process between aggregates and native animals allows us to probe the development of robust architecture in these animals using a few cell types. Our current work opens doors to building artificial animals with non-native cellular compositions, further enabling us to decipher the role of various cell types in this self-organization process.

S5-6 WADA, H; Auburn University; *haruka@auburn.edu*

Damage-fitness model: Integrating stress physiology models

Over the last decade, several theoretical models have been put forth to describe how animals respond to an adverse environment and how this response changes throughout the animals' lives and physiological demands. These models capture the context- and condition-dependent nature of stress responses. However, application of the models has been limited thus far because each model addresses different aspects of the problems facing the field of stress biology. Thus, there is a need for a unifying framework that integrates existing models of stress physiology and incorporates changes in physiological demand with life history stages and age, intricate relationships among physiological systems, and biphasic nature of stress responses. Here, I describe a new framework of the Damage-Fitness Model. In this model, regulators, such as DNA repair, inflammatory response, and glucocorticoids, change constantly and act as anti-damage mechanisms to minimize damage caused by a stressor. When the anti-damage regulators are insufficient or inappropriate, damage accumulates. Previous studies indicate that these damages directly impact reproductive performance, disease risks, and survival. The types of stress responses, the threshold at which stress responses are initiated, and the magnitude of the responses are shaped by developmental and current environments. How those environments and stress response phenotypes alter fitness outcome will be discussed.

17-4 WAINWRIGHT, DK*; COLLAR, DC; GEMMEL, BJ; LAUDER, GV; Harvard University, Christopher Newport University, University of South Florida; *dylan.wainwright@gmail.com*

Fish scales: Structure, diversity, and hydrodynamic function

Fish scales are bony plates that cover the body of fishes in overlapping patterns. Most past work on fish scales used two-dimensional microscopy to qualitatively study structural features. Although valuable in describing major features of scale diversity, a full understanding of the form and function of scales requires study of their three-dimensional (3D) morphology and surface patterning. 3D morphology both increases our knowledge of the morphological diversity of fish scales, and also helps inform possible functions, such as protection and drag reduction. To that end, we have imaged and quantified 3D fish scale morphology in detail in single species, across species, and *in vivo*. Our results reveal considerable previously unrecognized scale variability both within and among species. Furthermore, our *in vivo* measurements of scale topography demonstrate that mucus and epidermis have the potential to greatly alter surface topography, with implications for the hydrodynamic function of fish skin surfaces. Preliminary analyses of flow over fish scales with and without mucus indicate that mucus changes near-surface flows in ways that reduce drag. We also present comparative surface topography data from 59 species of damselfishes and provide the first evidence that scale morphology responds adaptively to ecologically driven selection. Altogether, we argue that scales represent an important but largely unexplored axis of functional and morphological diversity in bony fishes. Our morphological, comparative, and functional data combine to portray the interactions between scales and mucus as well as their function and ecology to build a foundation for understanding the vast diversity of fish scales.

P1-289 WAINWRIGHT, DK*; LAUDER, GV; Harvard University; *dylan.wainwright@gmail.com*

The structure and hydrodynamic function of tuna keels

Tuna have laterally projecting wings of soft tissue at the narrowing of their body just anterior to their tail in the region of the caudal peduncle. These features are known as keels and have evolved independently multiple times in fast swimming bony fishes and in lamnid sharks. We use micro CT, histology, and simple robotic models to understand the morphology and function of these keels in tunas of the genus *Thunnus*. In these fishes, keels are extremely flexible and are composed largely of collagen with a cartilage rod running anterior to posterior. Previous research has suggested that lateral keels might decrease lateral forces experienced near the tail and reduce caudal torque of these high-performance fish by streamlining the caudal peduncle in the lateral direction. We test this hypothesis for the first time using simple physical models of tuna-like tails with and without lateral keels. We actuate these model tails in a flow tank using biologically relevant parameters based on kinematic data collected from captive tuna, and we compare performance of models with and without keels. Multi-axis force-torque sensors allow us to compare forces in the drag, thrust, and lateral directions to help elucidate any performance benefits of lateral keels. In addition, we can record and compare mechanical power consumption and self-propelled speed of keeled and keel-less models at a range of motion parameters and speeds. Experimental cases where keeled models outperform keel-less models can be further studied by imaging flow using particle image velocimetry.

PL-1 WAINWRIGHT, PC; University of California, Davis; *pcwainwright@ucdavis.edu*

Key innovation and diversity in fish jaws: A SICB story

The concept of key innovation is among the most unifying ideas in integrative and comparative biology. Key innovations are evolutionary novelties that allow organisms to interact with the environment in a novel way that facilitates expansion into a wide range of niches that were not previously possible. They are thought to be the main intrinsic driver of adaptive radiation, in which a lineage rapidly speciates and diversifies to fill available niches. While key innovations are of broad interest among biologists, the intricacies of how they work is a topic that sits squarely with the functional biologists that make their home in the Society for Integrative & Comparative Biology. In this talk I review one of the most famous examples of key innovation, the specialized pharyngeal jaws of cichlid fishes. In the 1970s, SICB's Karel Liem initially recognized the derived nature of cichlid pharyngeal jaws and proposed that this novelty is a key to their exceptional diversity because it allows these fish to feed on such a wide diversity of prey items. He later showed that this novelty is shared by three additional fish families and he used this observation to propose monophyly for cichlids, labrids, pomacentrids, and embiotocids in a group named Labroidei. Decades later, phylogenetic analyses of spiny-finned fishes began to carefully test this hypothesis, and through a series of studies the community concluded that the members of Labroidei are in fact not closely related, implying that the derived jaw system evolved independently at least five times. I present new results from a survey of thousands of fish species, that show that fishes with this novelty exhibit rates of body shape evolution that are almost twice that of lineages that lack the novelty, supporting the idea that the novelty spurs ecological diversification.

P1-169 WALDRON, J*; KAJIURA, SM; Florida Atlantic University; *kajiura@fau.edu*

Seasonal Abundance and Spatial Distribution of Blacktip Sharks (Carcharhinus limbatus) in Southeast Florida

Southeast Florida's marine ecosystem experiences a seasonal influx of upper trophic level predators each winter due to the large-scale annual migration of blacktip sharks (*Carcharhinus limbatus*). Blacktip sharks occupy shallow, coastal habitats and are distributed from Georgia to North Carolina during the late spring and summer, migrate south during the fall to overwinter in Florida, and then migrate north in late winter and early spring. As they migrate, blacktip sharks form dense aggregations along Florida's coastline. Although these large shark aggregations attract significant public interest, surprisingly little empirical data have been collected on the shark abundance, spatial distribution, and the factors driving their migration. Manned aerial surveys of coastal waters were conducted from Boca Raton to Jupiter (2011-2014), and Miami to Jupiter (2015-2018). A high definition video camera mounted out the open window of the plane recorded the transect to a distance approximately 200m seaward of the beach. These videos were analyzed to determine blacktip shark abundance, and shark densities within inlet-bound sections of the coastline. Water temperature was also recorded to examine correlations with shark abundance. Results indicate that the highest shark densities, exceeding 2,000 sharks km^{-2}, were in the northern-most sections of the transect (Palm Beach County) in February and March, when water temperature was at its lowest. Peak shark abundance was significantly inversely correlated with water temperature. This strong correlation between water temperature and shark abundance suggests that warming oceans might shift the southern terminus of the migration towards higher latitudes, causing ecological changes along the United States Eastern seaboard.

76-3 WALDROP, LD*; HE, Y; KHATRI, S; New Mexico Tech, UC Merced; *lindsay.waldrop@nmt.edu*

Hairy noses and fast computers: exploring odor capture with hair arrays using computational modeling

Many animals rely on gathering information from their environments by capturing chemical signals (odors) from environmental fluids. Odor capture is commonly accomplished in aquatic crustaceans and insects with arrays of hair-like chemosensory sensilla. The arrangement of sensilla in these arrays differ broadly between animals living in air and water. The physical properties between air and water also differ, including density, viscosity, and the diffusion rates of odorant molecules. In this study, a computational advection-diffusion model of odor capture by a hypothetical sensilla array was used to determine how the physical differences of air and water affect the morphology of sensilla arrays. We use this model to explore the space associated with three parameters characterizing the arrangement and kinematics of sensilla arrays (gap-width-to-diameter ratio, Reynolds number, angle of the array with respect to flow). Through uncertainty analysis of the model, we find that there are should be distinct signals in the variance of these parameters in aquatic and terrestrial animals.

35-8 WALKER, B.G.*; VILLANUEVA, C.; BERTELLOTTI, M.; BOERSMA, P.D.; Fairfield University, Universidad Nacional del Comahue, Universidad del Chubut, University of Washington; *bwalker@fairfield.edu*

Potential of epigenetic effects in penguin chicks hatched in tourist-disturbed areas of breeding colonies in Argentina

Penguins are charismatic birds that people want to see in the wild. How such tourist visitation affects birds at breeding colonies worldwide has been the focus of extensive study. In Magellanic penguins (*Spheniscus magellanicus*) we have shown that penguins appear relatively robust to tourist visitation. There are, however, some interesting physiological impacts on penguins that experience tourist visits, particularly in colonies with higher levels and a longer history of visitation. We compared two colonies with different levels and history of tourism, and show that in eggs laid in the tourist area of the most visited Magellanic penguin colony in Argentina - Punta Tombo - recently hatched chicks show an unexpectedly high glucocorticoid stress response, regardless of where the eggs were incubated/hatched (as determined via egg exchange studies). In contrast, both in eggs laid in areas at Punta Tombo without tourist visits, and in eggs in both tourist-visited and un-visited areas at a less extensively visited Argentine colony - San Lorenzo - eggs produce chicks with the expected low "hyporesponsive" glucocorticoid stress response regardless of where they are hatched. We discuss the potential of this phenomenon as an epigentic effect passed to chicks from parents. Future research will be directed to determine the potential causes and effects of this response.

P1-258 WALKER, MA*; ASHER, VJ; URIBASTERRA, MG; CAMPIONE, AM; RYAN, SJ; BLACKBURN, JK; University of Florida, Turner Enterprises; *m.walker@ufl.edu*

Ungulate use of locally infectious zones (LIZs) in the re-emerging anthrax zone of Southwestern Montana

Environmentally mediated indirect pathogen transmission is explicitly linked to host movement and foraging in areas where pathogens are maintained in the environment. In the case of anthrax, spores of the causative bacterium *Bacillus anthracis* are released into the environment following host death creating localized infectious zones (LIZs). In grassland anthrax systems, the most likely route of infection in herbivores is ingestion of spores while grazing at LIZs. Here we used camera traps to assess how ungulate species utilize carcass sites in Southwest Montana and evaluated how these behaviors may promote indirect anthrax transmission. Data were collected from August 2016 to September 2018 at 14 carcass sites (proxies for LIZs) and 13 control sites (comparable habitat without LIZ) for a total of 470,221 independent photographs during 12,533 camera trap days. Data analysis is ongoing; however, initial results suggest that adult male bison spend more time grazing at LIZs than calves, yearlings, or adult females. Similarly, adult male elk are more likely to graze at LIZs than control sites. These data are consistent with previous findings in the study area that during anthrax outbreaks adult male bison and adult male elk were disproportionately affected. Further, white-tailed deer (WTD), mule deer, and moose show no preference for LIZs over control sites; anthrax in WTD is rare in the study area and not reported in mule deer or moose. Serological surveys mirror these findings with little *B. anthracis* exposure in female elk and frequent exposure in males. Our findings suggest that LIZs promote grazing and differentially attract male and female hosts.

P1-228 WALTERS, LJ*; KIBLER, KM; COOK, G; CHAMBERS, L; DONNELLY, M; HAWTHORNE, T; RIVERA, F; University of Central Florida; *linda.walters@ucf.edu*

Integrating sense of place into ecosystem restoration: a novel approach to achieve synergistic social-ecological impact

It is a challenge to predict the impact of ecosystem restoration because many critical relationships and feedbacks between natural and human systems are poorly understood. To address this knowledge gap, we introduce a novel framework to characterize restoration dynamics within coupled human-natural systems. As dynamics surrounding restoration are complex, we investigate the potential for sense of place (i.e. emotional attachment to place) to elucidate relationships between human and natural systems during times of change, such as restoration. Integrating sense of place with ecological metrics, a typology of restoration scenarios that exemplify complex relationships between social and ecological drivers emerges. We propose an Identify-Visualize-Create framework for parsing restoration objectives and curating sense of place around the functional ecosystem state. Achieving coupled human-natural objectives thus requires evaluation of baseline sense of place early in the restoration process and active pursuit of opportunities that build stakeholder attachment over the long-term.

20-3 WALTERS, LJ*; SCHNEIDER, K; TRIPP, M; University of Central Florida; *linda.walters@ucf.edu*

Using Peer Coaches to Enhance Curriculum-Based, High-Impact Practices for Undergraduates

High-impact educational practices (HIPs), including undergraduate research, service-learning, study abroad and community engagement, produce successful students with the critical thinking skills, communication proficiency, and the ability to solve complex problems. Yet, growing the number of HIP opportunities at an institution, especially a large institution, remains a challenge. Here we review a model that embeds faculty-selected, peer HIP Coaches, as a resource for the students in undergraduate courses. Coaches receive a small scholarship in exchange for 30 hours of assistance and their role in each course was determined by the faculty mentor to best match each unique course agenda. A pilot in 2015 with 4 faculty, 8 coaches and 250 students, was successful. In the spring 2018 semester, the model grew to include 21 faculty, 37 coaches, and 1111 undergraduates. Everyone wins with this model - faculty can maximize HIP student learning and success, peer coaches receive leadership experience, and the undergraduates in the course receive needed and wanted high-impact experiences that positively impact their lives and livelihoods.

31-5 WANG, S; LI, L; CHEN, Y; KENALEY, CP; WAINWRIGHT, DK; WOOD, RJ; WEN, L*; Beihang University, Harvard University, Boston College, Harvard University; *liwen@buaa.edu.cn*

The detachment of remora: kinematics, dynamics, and a bio-robotic model

Remoras have the extraordinary ability to attach to a wide variety of marine surfaces as well as to detach rapidly. To investigate how remoras detach, we conducted experiments on living remoras (Echeneis naucrates), and further developed and evaluated a bio-robotic remora disc. We captured and analyzed synchronized high-speed videos, measured external normal and shear forces, and the inner disc chamber pressure of living remoras (body length: 28 ±1.0 cm) during the attachment and detachment processes. Results from the high-speed videos show that living remoras can detach within 220 ms, with a maximum detachment angular velocity of 6.4 rad/s. To achieve rapid detachment, remoras fold down the disc lamellae away from the attached surface, and then curl the disc lip upward (away from attached surface) starting from the disc anterior. Using contrast stained µCT of Remora remora, we showed that the muscle around the soft disc lip can trigger/initiate the disc lip's curling motion. Based on the described kinematic and morphological features, we developed a multi-material bio-robotic disc (whose stiffness spans from 0.5 Mpa to 200 Gpa) that enables both attachment and detachment. Detachment in the bio-robotic disc mimics the motion of a biological lamellae and the disc lip, and the contact has been visualized through the FTIR approach. During detachment, we found that the pulling force of the robot is reduced by over 250 times compared to that of the fully attached state. Repeated underwater attachment and detachment were demonstrated through incorporating the biomimetic disc on an underwater swimming robot. We hope that this study will inform the development of an untethered robotic system for underwater hitchhiking in realistic aquatic environments.

115-1 WANG, J*; TRAN, H; CHRISTINO, M; WHITE, CH; ZHU, J; WAINWRIGHT, DK; LAUDER, GV; BART-SMITH, H; DONG, H; University of Virginia, T.C. Williams High School, Harvard University; *justinwang2011@gmail.com*

Understanding Thunniform Swimming: Kinematics and Hydrodynamics

Hydrodynamics and force production mechanism of thunniform swimming is numerically studied by using a tuna-inspired underwater vehicle (TunaBot) in forward swimming. The numerical modeling approach employs a sharp-interface immersed-boundary-method (IBM)-based incompressible flow solver. The three-dimensional, time-dependent kinematics of the body-fin system of the TunaBot is obtained via a stereo-videographic technique. A high-fidelity computational model is directly reconstructed based on the experimental data. The primary objectives of the computational effort are to quantify the thrust performance of the TunaBot at different Reynolds number as well as to establish the mechanisms responsible for thrust production. Comparisons in body kinematics, hydrodynamic performances, and wake structures are made between the TunaBot and an Atlantic bluefin tuna at similar swimming condition to bring insight in understanding the difference in thrust producing mechanism between TunaBot and live thunniform swimming fish and to provide potential suggestions in improving the hydrodynamic performance of swimming underwater vehicles.

P3-155 WANG, Q*; HERNANDEZ-OCHOA, E; BLUM, I; VISWANATHAN, M; GRANGER, J; YANG, J; LOVERING, R; SCHNEIDER, M; CAMMARATO, A; WU, M; BEVER, G; ANDERSON, M; Johns Hopkins Univ., School of Medicine, Univ. of Maryland, School of Medicine; *qinchuan.wang@jhmi.edu*

A Critical Role for Oxidative Regulation of CaMKII in the Origin of Vertebrates

Origins pose difficult problems for evolutionary biologists. Comparative analyses are powerful at identifying the stem lineage along which a particular feature finds its origin but relatively weak at providing details of the origin itself. Fossils can mitigate this weakness, and experimental biology is becoming increasingly adept at engineering meaningful outgroups and ancestral conditions. We explore the integration of these approaches for our understanding of vertebrate origins; in particular the emergence along the vertebrate stem lineage of a metabolically active, predatory existence from the sessile, filter-feeding ecology of our deuterostome ancestors. We identify oxidative-mediated activity of the Calcium/Calmodulin-Dependent Protein Kinase II (CaMKII) as a key innovation that helped facilitate the functional potential of such iconic vertebrate apomorphies as an internal skeleton, sympathetic nervous system, increasingly efficient respiratory and circulatory systems, prechordal head, and placode-derived organs of special sensation. Using mutant taxonomic strains that lie phylogenetically inside and outside crown-clade Vertebrata, we provide support that the acquisition of this oxidative-mediated kinase activity ushered in a number of novel modalities for stem vertebrates that included heightened performance of skeletal muscle. The cruel irony of these results is that the same oxidative regulatory pathway that likely played a key role in our early success as vertebrates is also identified in a number of human disease processes, including heart disease, pulmonary disease, and cancer.

110-2 WARBURTON, EM*; KHOKHLOVA, IS; VAN DER MESCHT, L; DOWNS, CJ; DLUGOSZ, EM; KRASNOV, BR; Ben Gurion University, Hamilton College, University of Tennessee; *warburte@post.bgu.ac.il*

Effects of flea infestation on offspring quality in a desert rodent: evidence for parasite-mediated transgenerational phenotypic plasticity

Parental effects may beneficially alter offspring phenotype if parental environment sufficiently predicts offspring environment. Parasitism is a common stressor across generations; thus, parental infestation could reliably predict the likelihood of infestation for offspring. Few experiments involving parasitism and maternal effects exist and none investigate this relationship across multiple generations. We investigated how maternal and grandmaternal infestation with fleas (*Xenopsylla ramesis*) affected offspring in a desert rodent (*Meriones crassus*). We used a fully-crossed design to examine litter size (LS), pup body mass at birth (PBM), and pup mass gain before weaning (PMG) for combinations of maternal and grandmaternal infestation status. No effect of treatment on LS or PBM was found. However, maternal and grandmaternal infestation status significantly affected PMG, a proxy for maturation, in male pups. These pups gained significantly more mass before weaning if maternal and grandmaternal infestation status matched, regardless of treatment. Thus, pups whose mothers and grandmothers experienced similar risk of parasitism could reach sexual maturity more quickly than those pups whose mother's and grandmother's infestation status did not match. These results support the contention that parents can receive external cues, such as risk of parasitism, that prompt them to alter offspring provisioning. In turn, this provisioning is beneficial if the parental environment matches that of the offspring. Thus, parasites could be a mediator of environmentally-induced maternal effects and could affect host reproductive fitness across multiple generations.

P3-164 WARNER, DA*; HALL, JM; HULBERT, A; TIATRAGUL, S; PRUETT, J; MITCHELL, TS; Auburn University; *daw0036@auburn.edu*

Recent Extinction of a Viable Tropical Lizard Population from a Temperate Area

Human activity is responsible for numerous introductions of species to areas outside of native ranges. However, because many introduced populations may not persist long enough to be noticed, and hence remain unreported, the factors responsible for population establishment or extinction are often difficult to quantify. We studied a viable population of brown anoles (*Anolis sagrei*; native to Cuba and The Bahamas) at a temperate latitude that is farther north than its continuous invasive range in the southeast United States. This population was first reported in 2006 at a commercial greenhouse near Auburn, Alabama and likely arrived via propagules transplanted in ornamental plants. The warm confines of the greenhouse presumably shielded this population from lethally cold winters for at least 12 years (~12 generations). However, the greenhouse rapidly degraded after the facility went out of business (in 2016) and lost its roof due to strong winds from Hurricane Irma (in 2017). Prior to winter 2017, individuals of both sexes and all age classes were present (from eggs to adults), and the population size was at least 225 individuals. Post-winter surveys in 2018 revealed that no *A. sagrei* survived winter. Without the thermal buffering of the greenhouse roof, temperatures dropped well below the population's critical thermal minimum, and individuals were presumably exposed to lethally low temperatures. This study provides a rare documentation of an extinction of a viable introduced population and illustrates the role that anthropogenic structures and natural weather events play in population establishment and extinction.

136-5 WATANABE, A*; FELICE, RN; MAISANO, JA; MÜLLER, J; HERREL, A; GOSWAMI, A; NY Institute of Technology, Old Westbury, University College London, London, University of Texas, Austin, Museum für Naturkunde, Berlin, Muséum national d'Histoire naturelle, Paris, Natural History Museum, London; *awatanab@nyit.edu*

First Squamate-Wide Phenomic Analysis Reveals Conserved Pattern of Cranial Integration Underlying Mosaic Skull Shape Evolution

Large-scale evolutionary studies typically have invoked extrinsic factors (e.g. environment), but intrinsic factors, such as developmental constraint, ultimately shape the variation available to natural selection. While comprehensive studies on cranial evolution in birds and mammals have analyzed how patterns of trait covariation have influenced their diversification, parallel investigations into other major vertebrate clades remain elusive. With >10,000 known extant species, squamates (lizards, snakes) exhibit remarkable variation in cranial morphology and ecological modes. To identify the integrated structures that underpin their cranial disparity, we present the first squamate-wide analysis of cranial shape harnessing a new, high-dimensional geometric morphometric dataset comprising ~1,000 3D landmarks and ~200 modern and extinct species. With this rich phenotypic dataset, we identify a shared set of highly integrated regions in lizards and snakes despite their fundamental differences in form. Meanwhile, we find no evidence that the magnitude of trait integration within those regions has constrained or promoted phenotypic evolution across squamates. In fact, our analyses demonstrate highly mosaic patterns across these cranial regions that dictate morphological novelty and disparity, particularly those associated with fossoriality, major changes in diet, and elaborate cranial ornamentations. Our results also suggest that earlier ossifying regions exhibit weaker trait integration. Collectively, this study highlights the incredible potential of an emerging class of comparative studies that combines high-density morphological data with modern evolutionary analyses.

132-4 WATKINS, MJ*; BROWN , HM; RUBEGA, MA; University of Connecticut ; *mackenzie.watkins@uconn.edu*

Hiding in Plain Sight: Do Brown Trout Background Match in Simple Environments?

In structurally complex environments, fish have two choices when faced with predation: flee or hide. Habitat degradation tends to structurally simplify aquatic habitats, resulting in limited access to hiding spots. Since juvenile fish are most at risk from predator-induced mortality, habitat degradation may affect juveniles disproportionally. We examined background matching, in which animals position themselves over areas that are not visually similar to themselves instead of fleeing, as a possible behavioral response in predator-naïve brown trout (*Salmo trutta*) when exposed to a great blue heron decoy in a simple environment. We recorded overhead video of predator-naïve brown trout exposed to a heron decoy and a control in tanks with randomly distributed dark substrate patches over a light-colored floor. We digitally tracked trout position during reactions to the decoy and control using DLTdv6 through MATLAB, and tracked pathway, distance moved, and time spent over dark versus light substrate. Our results showed strong support for predator-naïve fish responding to a heron decoy. Fish exposed to a heron decoy deviated from the shortest path away from the heron decoy, and spent more time over dark substrate. We found that group size influences trout response, with larger groups of fish more likely to remain in light areas during exposure to the heron decoy. Our data suggests that small groups of predator-naïve brown trout attempt to background match, possibly due to greater chances of predation on a single fish. Our research has implications for predation outcomes for predator-naïve brown trout, such as hatchery-raised fish, in degraded and simplified environments.

80-1 WATSON, DA*; KAHN, HA; DIAMCO, RC; DICKERSON, AK; University of Central Florida; *andrew.dickerson@ucf.edu*

On the survival of water striders during raindrop impacts

Water striders are abundant in areas with high humidity and rainfall. Raindrops can weigh 20 times the insect and some pelagic species spend their entire lives at sea. In this combined experimental and theoretical study, we use high-speed videography to film raindrop collisions on water striders and dynamically scaled mimics. Raindrops force the insect subsurface upon direct impact. As the ensuing cavity collapses, the strider is shot into the air alongside a Worthington jet. We show the insect's rigid exoskeleton, low density, resistance to wetting when briefly submerged and its ability to regain an equilibrium rest state, render it impervious to impacting droplets. In the event of cuticle wetting, raindrops become dangerous and submersion makes the water strider incapable of penetrating the air-water interface from below, which appears impossible without the aid of a plastron. Indirect impacts elicit jumps as the strider maneuvers surface perturbations. Our findings show water striders are robust to adverse environmental conditions and augurs well for the development of biomimetic robots.

P1-221 WATSON, A*; GEORGE, SB; Georgia Southern University, Statesboro, GA, Georgia Southern University Statesboro, GA; *georges@georgiasouthern.edu*

Does Shading by Cordgrass Reduce Physiological Stress in RIbbed Mussels in a Local Salt Marsh?

According to NOAA, the highest temperature in the US was recorded in 2016, followed by the third highest in 2017. Rising temperatures and increasing drought frequency could affect marsh health, though in the presence of ribbed mussels, *Geukensia demissa*, marsh recovery can take as little as 10 years versus 100 years without them. Mussels are usually found on mounds (raised portions of the substrate), at the base of cordgrass, *Spartina alterniflora* stems. These two species, along with others, work together to maintain the health and biodiversity of the marsh. But as temperatures rise they may be undergoing considerable stress. This study will examine whether cordgrass provides enough shade to decrease stress and enable increase in mussel abundance despite the increase in temperatures in the salt marsh. Eight large mussel mounds (198-243 cm in diameter) with similar cordgrass densities were flagged in the mid-zone of a local saltmarsh at Tybee Island, Georgia. Four of these mounds were tagged as short cordgrass mounds (cordgrass ≤ 40cm, less shade) and the other four as tall cordgrass mounds (cordgrass ≥ 60cm, shaded). During the Spring and Fall of 2018, temperature, sediment organic content, mussel abundance, cordgrass density and height were recorded. In September, three mussels/mound were collected. In the lab, mussel tissue was lysed, and the supernatant was stored at -80°C. Ten microliters of the sample were used to determine total protein concentration. Our results revealed significantly higher sediment organic content and mussel abundance on mounds with tall cordgrass (100-173 mussels/mound) than on mounds with short cordgrass (51-132 mussels/mound). These results further indicate the importance of the interaction between these two species in maintaining salt marsh health.

122-2 WATSON, CM*; DEGON, Z; KROGMAN, W; COX, CL; Midwestern State University, Georgia Southern University, Noble Research Institute; *charles.watson@mwsu.edu*

The adaptive significance of an ontogenetic shift in coloration among skinks.

Many organisms possess antipredator traits that confuse, decoy, or startle predators to decrease mortality from predation. Paradoxically, some of these antipredator traits are present only in juveniles, with antipredation traits lost during ontogeny. While potential drivers of ontogenetic loss of antipredation traits can include shifts in predators, prey, or intraspecific competition, the specific factors that drive the loss of antipredation traits with ontogeny are not well known. We studied the ontogenetic loss of the bright-blue tail of skinks, which diverts predatory strikes away from vital body parts towards the tail. We used 1) a survey of morphology and body size of three skink species, 2) a clay model study of predation rates, and 3) a study of body and tail energetics to determine the factors that drive ontogenetic loss of the blue tail. We found that the blue tail is lost at the same size among three different species of skinks, which implies similar selective forces drive the loss of the blue tail among these species. We also found strong support that the ontogenetic shift in coloration is related to differences in predation pressure with increased size, and not differences in energetics of tail loss. Our findings illustrate how predation can drive complex expression of antipredation traits, which has implications for understanding the evolution of phenotypic diversity.

S6-6 WATSON, Eric T.*; EDMANDS, Suzanne; University of Southern California; *ericwats@usc.edu*

Mitonuclear coevolution and the genetics of speciation in Tigriopus californicus.

Eukaryotic biology is genetically encoded by a nuclear genome and one or many cytoplasmic genomes. The division of labor between these organelles requires their functional and evolutionary integration and has important implications in evolution, conservation, and medicine. The mitochondrial genome is especially prone to accumulating deleterious mutations which may disrupt mitonuclear integration thus favoring the recurrent evolution of nuclear restorers of mitochondrial function. In addition, uniparental inheritance may contribute to an 'asymmetric sieve' resulting in sex-specific fitness effects especially in hybrids. Mitonuclear conflicts may therefore be an important driver of postzygotic isolation between diverging populations. Here, we present recent work on the genomic signatures of mitonuclear coevolution across eight populations of the copepod *Tigriopus californicus* and investigate the possibility of sex-specific genetic architecture for postzygotic isolation. Populations of *T. californicus* show extreme mitochondrial DNA (mtDNA) divergence, with an average of 19.6% nucleotide divergence across the genome, as well as high levels of amino acid differentiation. Nuclear encoded genes predicted to interact with mtDNA and products show elevated rates of protein evolution, indicating compensatory nuclear evolution. In fourth generation recombinant inbred lines between populations, hybrid incompatibility is distributed widely throughout the genome with males suffering almost ten times the amount of hybrid incompatibility than females. Together, these results reveal the potential importance of mitonuclear coevolution as a driver of population differentiation and the evolution of hybrid incompatibility as well as the presence of sex-specific genetic architecture of hybrid incompatibility in *T. californicus*.

85-3 WATTS, HE*; ROBART, AR; ROBY, C; RITTENHOUSE, JL; SEWALL, KB; BOWERS, JM; Washington State University, Virginia Tech, Virginia Tech; *heather.watts@wsu.edu*

Examining the potential role of glucocorticoid signaling in the regulation of seasonal nomadic migration

Most of what is known about the mechanisms regulating the transition to a migratory state comes from studies of species that make obligate migrations - regular and predictable movements to and from the same locations. In contrast, very little is known about the regulation of nomadic migrations, which occur unpredictably in space and/or time. For some nomadic migrants, there is a seasonal component to their movements, with a temporal window when migration is most likely to occur. In one such nomadic species, the pine siskin (*Spinus pinus*), we have found that increasing spring day lengths stimulate physiological preparations for migration and expression of migratory restlessness. Here, we examine the potential role of changes in glucocorticoid signaling - implicated in other forms of migration - in the transition to a nomadic migratory state. Using captive wild-caught pine siskins, we compared circulating corticosterone levels and expression of glucocorticoid receptor (GR) and mineralocorticoid receptor (MR) mRNA in key brain regions in birds before and after the onset of spring migratory restlessness. We found no change in circulating corticosterone levels as birds transitioned to a migratory state. We similarly found no differences in the expression of *GR* or *MR* in the hypothalamus or hippocampus of birds expressing spring migratory restlessness compared to those sampled before the onset of migratory restlessness. Our results do not suggest a significant role for changes in glucocorticoid signaling in the expression of a seasonal window for nomadic migration in pine siskins. These results are in contrast to evidence for a role of glucocorticoid signaling in some obligate migrations and in other forms of facultative migration.

89-5 WEAVER, R.J.*; HILL, G.E.; Auburn University; *rjw0019@auburn.edu*

Exploring links between mitochondrial divergence, hybridization, and carotenoid metabolism in animals

A key question in evolutionary biology concerns the mechanisms by which sexual displays serve as uncheatable signals of condition. It has been proposed that the process of metabolizing dietary carotenoids into sexual signals may be the basis for honest signaling for many color displays. Most animal diets contain only yellow carotenoids such as lutein and zeaxanthin. To display red carotenoid coloration, animals must metabolically convert these yellow carotenoids to red. Numerous studies on birds, fish, and reptiles have demonstrated that the hue and saturation of red carotenoid-based color displays is associated with the condition and quality of individuals. We recently proposed that carotenoid-based ornaments are an index signal of mitochondrial performance because the conversion of yellow dietary carotenoids to red carotenoids shares a pathway with redox reactions of mitochondrial respiration. Here we test predictions of this hypothesis by comparing how the effect of hybridization on carotenoid metabolism differs between hybrids of species with either deep or shallow mitochondrial divergence. We find that hybrids show breakdown in carotenoid metabolism when the parental species are deeply diverged, and vigor when parental species are shallowly diverged. We discuss the results in the context of the evolution of honest signaling from carotenoids in animals.

P1-187 WEBB, AC*; LILLY, N; WOOD, J; WARREN, C; HUDSON, S; FRENCH, SS; Utah State University; *alisoncarey4@gmail.com*

Interactions of behvaior, temperature, and metabolism in response to an immune challenge in side-blotched lizards, Uta stansburiana

The goals of this study were to **1)** understand how a measure of innate immune function, bacterial killing ability, responded to different immune challenges, **2)** how environmental temperature and lizard thermoregulatory behavior influenced this immune response, and **3)** how metabolic rate was altered during an immune response. To accomplish this, three separate experiments were performed. In the first experiment, lizard bacterial killing ability (BKA) was measured following a cutaneous wound, lipopolysaccharide (LPS), or phytohemagglutinin (PHA) challenge while lizards were allowed to thermoregulate. We found that the LPS challenge, but not PHA or a cutaneous wound, significantly increased BKA and that all lizard plasma, regardless of treatment, performed better at higher assay incubation temperatures. In the second experiment, lizard thermoregulatory behavior in response to an LPS challenge was monitored and quantified. We found that LPS challenged lizards spent more time in warm zones of the thermal gradients when compared to the control treatment. Finally, we measured immune function and metabolic rate of lizards in response to an LPS challenge when lizards were held at a constant temperature. In this experiment, we found that BKA was higher for lizards held at the warm temperature and that the LPS treatment groups for both temperatures had higher BKA compared to the control animals held at the same temperature. Metabolic rate increased following the LPS challenge but decreased or did not change for control animals. Together, these results demonstrate the importance of assessing the environmental context and individual variation when interpreting immune measures.

P3-122 WEBB, EA*; MCGRAW, KJ; Arizona State University, Tempe; *eawebb1@asu.edu*

Variation in Tissue Carotenoid Profiles: A Tale of Two Species

Carotenoid pigments are fat-soluble nutrients that are obtained via the diet and have diverse physiological and morphological functions. Despite all the attention paid to internal carotenoid functions in animals, surprisingly little has been paid to where in the body carotenoids may be exerting their functions, even though there is evidence of function-associated tissue allocation of carotenoids. As part of two separate studies, we characterized the tissue carotenoid profiles of two different carotenoid-colored species, king quail (*Excalfactoria chinensis*) and house finches (*Haemorhous mexicanus*). For the king quail, we manipulated an environmental variable and measured the effect on their carotenoid profiles. For the house finches, we measured the natural variation across sexes and seasons. In king quail, we found that the environmental variable had an effect on their carotenoid profiles, and there were sex differences in how the carotenoids were distributed generally. House finch carotenoid profiles are different from king quail carotenoid profiles. Further analyses will reveal if there are seasonal differences and/or sex differences among house finches.

P2-14 WEBSTER, NB*; MEYER, NP; Clark University; *nwebster@clarku.edu*

How conserved are centralized nervous systems across Bilateria? Investigating the role of BMP receptors in specifying neural fate and the dorsal-ventral axis in the marine annelid Capitella teleta

The repeated evolution of key features is a theme in evolution, but whether centralized nervous systems (CNSs) fit this pattern is still under debate. Within Bilateria, the three main clades (Deuterostomia, Ecdysozoa, Spiralia) all show a great diversity in CNS development. In vertebrates and insects, specification of neural ectoderm is largely a result of inhibition of BMP signaling during dorsal-ventral axis specification. This in conjunction with the discovery that BMP signaling has been involved in specification of the directive axis in at least some cnidarians—albeit not for neural specification—and thus possibly prior to the evolution of bilaterians, has led to a hypothesis that BMP signaling in axis formation, and possibly CNS formation is homologous across Bilateria. Under this hypothesis, the full diversity of CNS morphologies, such as a dorsal vs ventral nerve cord or degree of cephalization, may result from later diversification from a single primordial CNS. Sorely lacking to complete our understanding of evolution of CNSs is data from the third major group of bilaterians, Spiralia. Initial attempts to understand the role of BMP signaling in spiralians contradicts the idea of homologous CNS development, but further work is needed to thoroughly evaluate potential evolutionary scenarios surrounding the origin of bilaterian nervous systems. Here we investigated the role of BMP type 1 and 2 receptors during development of the spiralian annelid *Capitella teleta* to deepen our understanding of CNS formation in the third major clade of Bilateria.

123-2 WEIGHMAN, KK*; MOORE, PA; Bowling Green State Univ.; Univ. of Michigan Biological Station; *kkweigh@bgsu.edu*

Modeling Dynamic Exposure in Flow

In flowing environments, the movement and distribution of anthropogenic chemicals are determined by the degree of turbulent flow. As such, toxicant exposure for stream organisms is shaped by flow. Whether a toxicant enters a stream through runoff or via groundwater contamination plays a large role in how that toxicant will move through the stream environment. The interaction of the toxicant mode of entry and stream hydrodynamics creates spatio-temporal variation in toxicant concentration. In different locations within a stream, the processes which give rise to chemical plume structure will vary as a function of local stream characteristics. Using an electrochemical recording system to extract data for the frequency, magnitude, and duration of exposure in artificial stream systems, we gain insight into how toxicant "hot spots" form in streams with different flow characteristics. From these measurements, geographic information systems and interpolation techniques can be used to predict chemical distribution throughout habitats. These methods were utilized to compare patterning of toxicant "hot spots" in streams of different flow velocities, with both mode of toxicant introduction (groundwater or runoff) and organism position in the water column (benthic, mid water column, or surface) taken into consideration. Variation in the structure of chemical exposure was used to construct three-dimensional toxicant hot-spot maps, accounting for the spatial and temporal fluctuations of fine scale exposure. This project aids in developing more realistic appraisal techniques for impacts of chemical pollution in flowing environments. Experimental systems must be designed to account for temporal and spatial variability in chemical concentrations at scales relevant to organisms of interest.

S9-12 WEIS, Virginia M; Oregon State University; *weisv@science.oregonstate.edu*

In Sickness and in Health: The Role of Innate Immunity in the Regulation of Cnidarian-Dinoflagellate Mutualisms

Corals engage in a mutualistic symbiosis with intracellular photosynthetic dinoflagellates. This intimate partnership forms the trophic and structural foundation of coral reef ecosystems. This presentation will examine the cellular and molecular mechanisms underlying the establishment, maintenance and breakdown of the symbiosis in coral- and anemone-dinoflagellate partnerships. Host innate immunity and symbiont strategies for modulating this immune response are central to the stability of the symbiosis. During onset and maintenance of symbiosis these mechanisms include lectin-glycan signaling, upregulation of the immunosuppressive TGF-beta pathway and changes in the sphingolipid rheostat and complement pathway. Coral bleaching, a severe threat to the health of reefs worldwide, is caused by global warming and results from dysbiosis: the collapse of the symbiosis. Studies suggest that coral bleaching is a host innate immune response to a compromised and stressed symbiont. This evidence includes increased nitric oxide levels, and host cell apoptosis and autophagy in heat-stressed animals, all well-known immune mechanisms in other systems to eliminate detrimental microbial invaders. Finally, I will discuss the international effort to rapidly develop a sea anemone model system to advance genetic techniques and new tools for the field to help save severally threatened corals.

S10-9 WELCH, AM*; INFANTE, A; REINING, A; College of Charleston, SC, Academic Magnet High School, Charleston, SC, South Carolina Governor's School for Science and Mathematics, Hartsville, SC; *welcha@cofc.edu*

When You Get Salty: Developmental Timing and the Consequences of Salinity Exposure in Toad Tadpoles

Salinization of freshwater ecosystems is an emerging environmental concern, as rising sea levels, intensified storm surge, road deicing salts, and land use changes can contribute to increased salinity in freshwater habitats. Elevated salinity can increase the demands of osmoregulation in freshwater organisms, and amphibians are particularly at risk due to their semi-aquatic life cycle and permeable skin. Tolerance to environmental challenges may vary during development, with individual- and population-level impacts dependent on the timing of exposure relative to the timing of vulnerability. In addition, among larval amphibians, the life history consequences of various stressors can vary with the timing of exposure to stress. We manipulated timing and duration of exposure to elevated salinity during larval development of southern toad (*Anaxyrus terrestris*) tadpoles, across three experiments, and examined effects on survival, larval growth, and timing of and size at metamorphosis. Tadpoles exposed to elevated salinity early in development were the least tolerant, suggesting an increase in tolerance during larval development. Life history effects also depended on the timing of exposure, suggesting a potential constraint related to a loss of developmental plasticity leading up to the metamorphic transition. Our results suggest that elevated salinity is most likely to affect population dynamics when experienced early during larval development. Further, through life history effects, even sublethal salinity exposure in the larval environment may influence success in subsequent life stages.

129-3 WELLER, HI*; MANAFZADEH, A; OLSEN, AM; HERNANDEZ, LP; CAMP, AL; BRAINERD, EB; Brown University, George Washington University, University of Liverpool; *hannah_weller@brown.edu*

An XROMM Study of Intra-oral Transport and Swallowing in Catfish

Most fish feeding studies focus on prey capture, especially during suction feeding. The other half of a feeding event - getting prey from the mouth to the gut - is just as essential for successful feeding. But this occurs inside the mouth, hidden from view, making it difficult to study how fishes handle prey intra-orally. In order to track intra-oral transport and swallowing, we used X-ray Reconstruction of Moving Morphology (XROMM) to study feeding in channel catfish (*Ictalurus punctatus*, n = 3). We marked the prey and seven bones on the left side of the head, recording a total of 25 feeding events. By reconstructing the 3D trajectories of the prey beads in the oral and buccal cavities, we were able to track how the fish move prey through the mouth, and the point at which the prey passes through the esophagus. Prey moves through the oral cavity at high velocities as a continuation of the suction event, but comes to a full stop once it reaches the pharyngeal basket, where it then moves in a slower, more complex path before being passed to the esophagus. This slow phase coincides with little motion in the head and no substantial mouth opening or hyoid depression, suggesting that pharyngeal raking, rather than hydrodynamic manipulation, is responsible for prey transport in the buccal cavity. By contrast, once the prey is past the esophagus, its motion is tightly correlated with a "gulping" motion (hyoid depression, pectoral girdle retraction, and mouth opening) in the head. Our results indicate that catfish use phases of pharyngeal and hydrodynamic manipulation to direct prey into the esophagus, but how these gulping motions are moving prey in the esophagus is unclear.

P1-274 WELLER, HI*; COHEN, KE; KACZMAREK, E; GIBB, A; BRAINERD, EL; Brown University, University of Washington, Northern Arizona University; *hannah_weller@brown.edu*

Using Tethers to Measure Food Transport in a Flatfish

Ray-finned fishes exhibit a variety of feeding adaptations, including modifications to the pharyngeal basket, which aids in food manipulation and transport. Testing how fish transport food requires tracking it through the head, but direct observation of transport is impossible once food disappears into the mouth. To overcome this obstacle and measure the food's location in the mouth, I tied monofilament marked at 5 mm intervals to food of two different sizes (20 and 40% of head length) and offered them to butter sole (*Isopsetta isolepis*, n = 4, 24 trials). By tracking the monofilament, I measured the approximate velocity and transit time of the food. Food always moves through the oral cavity at high speeds (1-4 body lengths/s) as a continuation of suction. Once the food reaches 60% of head length, however, it moves in a much slower ratcheting pattern (< 0.1 body lengths/s), pausing between periods of transport. In all trials for both food sizes, food spends the vast majority of the time (>90%) in the posterior region of the head, and between 30 and 50% of the time in the approximate location of the pharyngeal jaws. I was also able to correlate transport with the externally visible movements of the gills, oral jaws, urohyal. Surprisingly, food typically moves through the head with no substantial external motion, although there appears to be compressive opercular abduction for larger food in the buccal cavity. Transporting large food takes approximately three times longer than small food (10.1 vs. 2.8 s), but scaled kinematic profiles were nearly identical between the size classes. Given its simplicity, the method described here provides a number of useful measurements of food transport, and could be applied across a variety of species.

21-3 WELLING, EM*; BURNETT, L ; MCELROY, E; University of Charleston, SC, College of Charleston; *wellingem@g.cofc.edu*

Aerobic scope of cultured juvenile red drum, Sciaenops ocellatus, at high summer water temperatures

Many estuarine organisms are frequently exposed to high water temperature and the accompanying reduction in water oxygen concentration. High water temperature also increases fish metabolic rate and therefore overall oxygen demand. Both routine and maximum metabolic rates (RMR and MMR, respectively) increase with temperature to maximum values at their optimum temperatures, and then decrease as temperature increases past optimum. Aerobic scope is the difference between MMR and RMR and represents aerobic metabolic capacity that can be used for activities such as locomotion, foraging, and digestion. Thus, reduced aerobic scope at non-optimal temperatures may inhibit physiological performance and alter behavior. This study investigates the effect of high temperature on aerobic scope and swimming performance of juvenile red drum. Oxygen consumption was measured at four temperatures mimicking summer temperatures in South Carolina: 24°C, 27°C, 30°C, and 33°C. Fish were starved, and RMR was measured overnight using respirometry. After RMR measurements, fish were exercised and placed back into the respirometer to estimate MMR. RMR was 13.47 ± 0.67 (mean ± S.E.) mmol kg^{-1} h^{-1} at 24°C and increased with temperature to a maximum value of 17.49 ± 0.87 mmol kg^{-1} h^{-1} at 33°C. MMR and aerobic scope peaked at 27°C (56.02 ± 2.82 and 39.99 ± 2.73 mmol kg^{-1} h^{-1}, respectively) and decreased at temperatures lower and higher than this optimum. RMR demanded a larger proportion of the oxygen consumed as water temperatures increased, resulting in decreased aerobic scope. However, aerobic scope did not decrease significantly at the highest temperature tested, and so performance in the wild may not be reduced at high summer temperatures.

P1-50 WELLS, LA*; HERNANDEZ, LP; STAAB, KL; McDaniel College, The George Washington University ; *law016@mcdaniel.edu*

Kinematics of cypriniform suction feeding: emerging patterns of functional diversity across sixteen species

The capturing of prey in a dense and viscous environment presents many hydrodynamic challenges for aquatic organisms. Suction-feeding fishes, like bluegill, have solved this problem by coordinating the timing of feeding movements (e.g., peak gape and peak premaxillary protrusion) in an all-or-nothing rapid expansion of the head. These peak movements are correlated with peak flow that draws prey into the buccal cavity. While this suction-feeding mechanism is common, goldfish have been previously shown to not fit this exact model. It has been observed that goldfish can sustain maximal flow for longer than bluegill, but the kinematics behind generating this flow profile are not yet known. Goldfish are members of the order Cypriniformes, a diverse group of freshwater fishes that all have a kinethmoid bone that aids in premaxillary protrusion and is not present in other fishes. In this study, we sought to quantify the relationship between morphological and kinematic variables of cypriniform feeding mechanisms. Because goldfish may not represent all cypriniforms, sixteen species were analyzed to attain a broad, phylogenetic sampling of this diverse order. Based on collected kinematic data of cypriniform feeding mechanisms, several patterns emerged. Bottom-feeding species show similar patterns to goldfish with sustained protrusion and slower times to peak gape while more derived species mirror bluegills and non-cypriniform kinematics with a faster time to peak gape and non-sustained protrusion. These findings suggest that cypriniforms do not fit a single model of suction-feeding and that diverse strategies for prey capture are found across the order.

54-3 WELLS, CD*; YERRACE, S; RAUTU, TS; SPENCER, D; SEBENS , KP; Univ. of Washington; *cdwells@uw.edu*

Population distribution and predator-prey relationships of the giant frilled anemone Metridium farcimen in the San Juan Islands

In the northeast Pacific, the giant frilled anemone *Metridium farcimen* forms dense aggregations on subtidal ledge and boulder communities and underneath floating docks in marinas. *M. farcimen* is a competitive dominant, excluding many of the other invertebrates that occupy primary space on walls and ledges, but details on its distribution and how the population is controlled are poorly understood. The distribution of *M. farcimen* was studied through extensive surveys at twelve locations in the San Juan Island archipelago. Current, light, and temperature at these sites was compared with the density of *M. farcimen*. Anemones were distributed along vertical walls in shallow communities (less than 18 meters), but become more abundant on sloping and horizontal surfaces deeper. *M. farcimen* populations are highly impacted by both light and current, but not temperature, preferring light levels insufficient to grow kelp and other tall macroalgae and current high enough to reduce sedimentation and deliver sufficient food. Abiotic and biotic factors help control this species from becoming an omnipresent competitive dominant.

P2-8 WELP, EW*; KOTARA, K; SHINKLE, J; Trinity University; *ewelp@trinity.edu*

Contrasting Results for Responses of Plants to Short Wavelength UV-B Radiation in Laboratory and Natural Light Environments

The differences in plant responses due to short wavelength ultraviolet-B radiation (UV-B) (290 - 300 nm) was evaluated in both laboratory and natural light environments (field studies). UV-B radiation has been observed to cause plants damage, in addition to leading to acclimation. We characterized response of Texas native grasses to full spectrum UV radiation and those receiving radiation that blocks the short wavelength UV-B. Big Bluestem *(Andropogon gerardi)*, Little Bluestem *(Schizachyrium scoparium)*, and Sideoats Grama *(Bouteloua curtipendula)* were used for the experiment. To test the effects of UV-B radiation, we used two types of treatments to generate differences in UV-B radiation, a UV supplementation protocol in a greenhouse and a pair of UV exclusion enclosures covering plants placed at sites across South Texas during summer (highest UV-B) and fall. For greenhouse supplementation treatments, plants were maintained in a greenhouse supplying no UV-B radiation and exposed for five days to either UV-B radiation excluding wavelengths shorter than 300 nm or UV-B radiation including 15% at wavelengths below 300 nm. From both field sites and greenhouse studies we found that effects of short wavelength UV-B tend to be species specific. For four different field sites, the exclusion of short wavelength UV-B caused a decrease in absorption at 330 nm in Big Bluestem ranging from 3% to 40%. Two greenhouse studies exhibited opposite results with the addition of short wavelength UV-B causing increases in 330 nm absorption ranging from 50% to 58%. Considering that both sets of plants were grown in the same pots and soil, and were kept watered, it appears that other unidentified abiotic factors were the cause of the marked differences observed.

S6-10 WERNICK, RI; CHRISTY, SF; HOWE, DK; SULLINS, JA; RAMIREZ, JF; SARE, M; PENLEY, MJ; MORRAN, LT; DENVER, DR; ESTES, S*; Oregon State University, Portland State University, Emory University; *estess@pdx.edu*

Sex and mitonuclear adaptation in experimental C. elegans populations

To reveal phenotypic and functional genomic patterns of mitonuclear adaptation, a laboratory adaptation study with *Caenorhabditis elegans* nematodes was conducted in which independently evolving lines were initiated from a low-fitness mitochondrial electron transport chain (ETC) mutant, *gas-1*. Following evolution, two distinct classes of lines representing different degrees of adaptive response emerged—a low-fitness class that exhibited minimal or no improvement compared to the *gas-1* mutant ancestor, and a high-fitness class containing lines that exhibited partial recovery of wildtype fitness. Many lines that achieved higher reproductive and competitive fitness levels were also noted to evolve high frequencies of males during the experiment, consistent with adaptation in these lines having been accompanied or facilitated by outcrossing. A highly non-random pattern of mitochondrial DNA mutation was observed within high-fitness *gas-1* lines, with parallel fixations of nonsynonymous base substitutions affecting gene products residing within ETC Complex I alongside the nuclear-encoded GAS-1 protein. Individual characterization of one of these mutations suggest that it was causal in the line's fitness recovery. Results provide convincing evidence for adaptation via mitonuclear epistasis, and indicate that mtDNA can be an important contributor to such evolution. Results will be discussed within the context of current hypotheses regarding mitonuclear adaptation and the evolution and maintenance of outcrossing.

16-3 WESTERMAN , E.L.*; RATHER , P.A.; HERZOG, A.E.; ERNST, D.A.; University of Arkansas , University of Arkansas; *ewesterm@uark.edu*

The effect of experience on mating behavior in Heliconius butterflies

Many animals have the ability to learn mate preferences. There is current debate over how this preference learning impacts speciation, as it is hypothesized to either enhance reinforcement, or facilitate the development of hybrid swarms. *Heliconius* butterflies, and *Heliconius melpomene* specifically, are a good model system for this area of research, because they have been used extensively for the study of hybridization, mate selection, and speciation and have a widespread diversity of color morphs. It remains unclear whether these butterflies can learn to prefer certain mates, and if previous social experience shapes adult mating behavior. Here we test whether previous social experience influences male mate preference for different *H. melpomene* races. We conducted no-choice behavioral assays to determine if latency to court and how often males courted (vs no courtship) differed between naïve males and males with previous exposure to a young, sexually mature, virgin female. To further test whether assortative courtship preference is learned in *H. melpomene*, males were either paired with a female who shared their phenotype, or one who did not. Preliminary results suggest that unsuccessful courtship has a negative effect on future male courting propensity, as experienced males court less often than naïve males. This negative effect of failed courtship on future courting efforts may be influenced by male innate preference, as there was a stronger effect of experience on males paired with females of their own phenotype than for males paired with conspecific females with different wing patterns. These results suggest that previous social experience may influence male mating behavior in *Heliconius* butterflies.

37-5 WESTERMEIER, A*; SACHSE, R; POPPINGA, S; KöRNER, A; BORN, L; MADER, A; BISCHOFF, M; GRESSER, GT; KNIPPERS, J; SPECK, T; University of Freiburg, Plant Biomechanics Group and Botanic Garden (PBG); Freiburg Center for Interactive Materials and Bioinspired Technologies (FIT), University of Stuttgart, Institute for Structural Mechanics (IBB), University of Freiburg, Plant Biomechanics Group and Botanic Garden (PBG); Freiburg Materials Research Center (FMF), University of Stuttgart, Institute of Building Structures and Structural Design (ITKE), University of Stuttgart, Institute for Textile and Fibre Technologies (ITFT), University of Freiburg, Plant Biomechanics Group and Botanic Garden (PBG); Freiburg Center for Interactive Materials and Bioinspired Technologies (FIT) ;
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Biology, biomechanics and biomimetic potential of Aldrovanda vesiculosa underwater snap-traps

The scarcely investigated aquatic waterwheel plant (*Aldrovanda vesiculosa*, Droseraceae) possesses the fastest snap-traps within the carnivorous plants (closure within 20 ms). The motion is induced by a small bending deformation of the midrib and the closure of the kinematically coupled trap lobes. However, the underlying actuation principle was thought to be purely hydraulically driven. Using a reverse biomimetic approach incorporating biological experiments and complementary computer simulations via Finite Element models, we were able to identify a combination of turgor change and the release of prestress as the driving forces of the movement, most probably speed-boosting the trap. We furthermore investigated water displacement during trap closure, the trap narrowing motion after fast closure and additionally, ecological aspects by analysing *Aldrovanda*'s natural prey spectrum. Moreover, going beyond biology, the geometric motion principle of *Aldrovanda* served as inspiration for the development of a biomimetic compliant shading device named Flectofold.

117-6 WESTNEAT, MW; University of Chicago;
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Mapping Anatomical Structure to Biomechanical Function in Musculoskeletal Lever and Linkage Systems

Musculoskeletal mechanisms yield output motion and force transmission determined by the configuration of anatomical components and the dynamics of muscle contraction. Computational models of these systems can help us to understand how morphology maps to function at different levels. How do we test for functional convergence in biomechanics? How do we define functional characters and determine when they are similar or equivalent? This study expands previous lever and linkage modeling, with software for more complete path analysis of linkage motion and simulation of structure-function relationships in a wide range of mechanisms, both simple and complex. Levers are often characterized as having one-to-one mapping, yet by incorporating muscle we find that simple levers are conclusively one-to-many. Four-bar linkages have been claimed to yield many-to-one (convergent) mapping, whereas simulations show that structural changes in four-bar linkages map to unique sets of primary functional variables (vector direction and magnitude of motion) so that linkages are in fact one-to-one. However, similar to levers, the dynamic role of muscle in powering linkages gives every individual linkage system a one-to-many capacity. Examples from cranial systems show that some biomechanical traits diverge and evolve due to linkage changes, and others in which muscle morphology is modified but linkages remain static. A protocol for defining convergent and divergent functional characters is proposed. Computational linkage modeling helps us to conclude that the geometry and physiology of muscles are critical to accurate estimations of lever and linkage function, that a more detailed path analysis of mechanical behavior helps to avoid some pitfalls of linkage comparison, and that multiple mechanical variables and levels of design should be considered when defining convergent or equivalent biomechanical systems.

P1-118 WESTRICK, SE*; STUDD, EK; BOUTIN, S; HUMPHRIES, MM; LANE, J; MCADAM, AG; DANTZER, B; University of Michigan, McGill University, University of Alberta, University of Saskatchewan, University of Guelph, University of Michigan ; *westse@umich.edu*

Methods of Measuring Maternal Behavior in a Wild Small Mammal

Behavior of small mammals can often be difficult to actively observe in the wild due to their secretive nature. In particular, maternal care behavior is often performed in enclosed areas, making frequent or continuous behavioral observation of mothers interacting with pups during development near impossible. Much of our understanding of the neuroendocrine mechanisms contributing to maternal behavior stems from small mammal research conducted in laboratory environments. By developing methods to measure maternal behavior in a wild small mammal, we can expand our understanding of maternal behavior by investigating natural variation and ultimately fitness consequences of this variation. By using accelerometer collars with temperature sensors on wild red squirrels, we measured multiple behaviors, including nest usage, without direct observation of the animal. Additionally, we used brief observational periods during standardized nest entries to gather a metric of maternal motivation. Using these data, we compared frequency and duration of nest entries of lactating squirrels with maternal retrieval behavior observed during nest entries. We also compared activity levels while in the nest between lactating and non-breeding red squirrels to identify a specific movement signature of interacting with pups as opposed to resting in the nest. Additionally, we used data collected from squirrels in a glucocorticoid supplementation experiment to investigate the effects of maternal glucocorticoids during pregnancy or lactation on these behavioral measures.

30-7 WHEELER, LC*; SMITH, SD; University of Colorado-Boulder; *lucas.wheeler@colorado.edu*

Computational Modeling of Anthocyanin Pathway Evolution

Alteration of metabolic pathways is a key component of the evolution of new phenotypes. Flower color is a striking example of the importance of metabolic evolution in a complex phenotype, wherein shifts in the activity of the underlying pathway lead to a wide range of pigments. Although experimental work has identified common classes of mutations responsible for transitions among colors, we lack a unifying model that relates pathway function and activity to the evolution of distinct pigment phenotypes. One challenge in creating such a model is the branching structure of pigment pathways, which may lead to evolutionary trade-offs due to competition for shared substrates. In order to predict the effects of shifts in enzyme function and activity on pigment production, we created a simplified kinetic model that mirrors the structure of anthocyanin pigment pathway. This model describes the production of the three major types of blue, purple and red pigments, and accordingly, includes multiple branches and substrate competition. We studied the behavior of this model by first identifying a state-space with realistic, functional parameter combinations. We then stochastically evolved the pathway between defined optima and mapped the evolutionary trajectories onto the state space. This approach allows us to quantify the probability density of trajectories through the state space and identify constraints. Finally, we test whether the observed trajectories and constraints match with experimental observations, i.e., the predominance of mutations which change color by altering enzyme expression as opposed to function. These analyses provide a theoretical framework which can be used to predict the consequences of new mutations in terms of both pigment phenotypes and pleiotropic effects.

P1-243 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 Sea Cucumbers: Contextualizing a Unique Echinoderm Across Evolution

Sea cucumbers are perhaps the most morphologically derived echinoderm; they possess a worm-like body plan, which sharply juxtaposes the pentaradial symmetry and armored body of other echinoderms. The group has evolved bizarre specializations such as anal suspension feeding, evisceration, sticky Cuvierian tubules that entangle attackers, and a "melting" body wall. Sea cucumbers are ubiquitous throughout all marine landscapes and include >1700 species in 25 families. Despite their diversity, abundance in the marine ecosystems, and economical importance as food, our understanding of their evolutionary history is limited. Here, we present a phylogenomic analysis of Holothuroidea using 9 unpublished and 16 published transcriptomes. Our analysis 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. We estimated clade divergence in BEAST and performed an ancestral state reconstruction analysis on 12 discrete traits using the Phytools package in R. This study provides an important initial framework that will allow us to further explore the evolution and biodiversity of this ecologically and economically important group of animals.

80-5 WHITEHEAD, JG*; SOCHA, JJ; Virginia Tech; *whijo23@vt.edu*

Do mallards landing on water exhibit tau theory strategies?

Birds are well known for their ability to fly. To avoid injury, a successful flight also demands a safe and precise landing. Previous studies have shown that birds regulate landing through a visual collision avoidance strategy, known as general tau theory. Tau theory predicts that collision can be avoided by regulating tau, the distance to collision divided by the rate of change of that distance. Birds not only regulate tau, but tend to keep the rate of change of tau itself constant; this is termed tau-dot constant. However, most studies on the biomechanics and control of landing in birds have been conducted with a perch in a laboratory setting, and its relationship to other landing modalities is unknown. In this study, we filmed birds landing in the wild to test if regulation of tau is present in a natural habitat. We filmed mallards (*Anas platyrhynchos*) landing on water at a local pond using three video cameras (GoPro Hero 4), with recordings synchronized post-hoc using sound. We used a 0.94 m wand to spatially calibrate the volume in conjunction with Argus 3D tracking software. The kinematics of landings were obtained by manually digitizing natural landmarks on the bird. Based on 23 landings, mallards exhibit a diverse range of landing trajectories, with approach angles as great as 40° relative to the water surface, and impact speeds from 0.8 to 7.5 m/s. Tau is highly linear regardless of landing trajectory or impact speed, with a mean linear correlation coefficient of -0.983 ($p < 0.001$). These results suggests that mallards use tau and tau-dot constant strategies, as seen in perch landing behavior.

P1-3 WHITENACK, LB*; STAAB, KL; DANOS, N; Allegheny College, McDaniel College, University of San Diego; *lwhitena@allegheny.edu*

What are the core concepts of vertebrate morphology?

Although there are entire journals dedicated to the teaching of medical anatomy, the pedagogical literature on teaching comparative vertebrate anatomy is lacking. This has created a situation where new instructors are lacking research into best practices and core concepts to teach. In addition, recent reports calling for change in science education ask that learning objectives focus on proficiency of core concepts. Focusing on core concepts, or big ideas, is thought to help students achieve meaningful learning, as they are transferable across sub-disciplines, foster retention, build problem-solving skills, and provide scaffolding for learning new concepts later. However, before we can employ these core concepts, we must define them. This interactive poster will discuss the pedagogy of core-concepts and serve as place to gather input on core concepts from SICB attendees in conjunction with the Teaching and Learning Workshop.

P1-104 WHITLOW, S. W.*; BUTLER, J. M.; MARUSKA, K. P.; Louisiana State University; *swhitl6@lsu.edu*

Behavioral, physiological, and neural correlates of ovulation in the African cichlid fish Astatotilapia burtoni

Ovulation in fishes occurs when eggs detach from the ovary lining and is associated with distinct behavioral and neuroendocrine changes. Despite these changes, gravid females are often grouped together independent of ovulation status. In female *Astatotilapia burtoni*, measures of gravidity (gonadosomatic index) correlate with affiliative behaviors and levels of circulating sex steroids. However, whether these changes are linked to ovulation, rather than gravidity, is not known. To investigate behavioral, physiological, and neural changes associated with ovulation, we collected gravid, naturally ovulated, and hormonally-induced ovulated females after interactions with a dominant male. The hormone prostaglandin F2α is commonly used to stimulate ovulation in fishes, but how closely it mimics natural ovulation remains unknown in most species. Naturally and hormonally-induced ovulated *A. burtoni* females performed more affiliative behaviors than gravid, non-ovulated females. Further, males court ovulated females more than non-ovulated females. Levels of circulating sex steroids (estradiol (E2) and 11-ketotestosterone (11-KT)) were higher in naturally ovulated females compared to non-ovulated females. PGF2α induced ovulation did not increase E2 and 11-KT levels, and lowered circulating levels of progestins. To understand where in the brain increased ovulation-regulated affiliative behaviors are mediated, we are using the neural activation marker pS6 to compare neural activation patterns in socially and reproductively relevant nuclei between ovulated and non-ovulated females. Together, these results provide an integrative approach towards understanding the behavioral, physiological, and neuroendocrine changes specifically associated with ovulation.

68-3 WHITNEY, C; DALEY, M; NISHIKAWA, K*; Northern Arizona University, Royal Veterinary College; *Kiisa.Nishikawa@nau.edu*

Muscles as length-dependent force generators.

Current models perform poorly at predicting muscle force during dynamic movements, especially for fast movements. We used a new muscle model to predict muscle force in running guinea fowl. Lateral gastrocnemius (LG) length, activation and force were measured by Daley et al. (2011). Data were recorded while guinea fowl ran on a treadmill modified so that obstacles were encountered at various phases of the step cycle. Trials included level running, 5 and 7 cm obstacles, and speeds from 1.8 - 4.5 m/s. The new model includes a damped contractile element (CE) in series with a spring representing extracellular matrix. The CE is in series and parallel with a damped titin spring. The titin spring wraps around a pulley that represents thin filaments. The CE rotates the pulley, adjusting the length and stiffness of the titin spring. The pulley translates when applied forces stretch or shorten the muscle, which changes the length and force of the titin spring. Free parameters include two spring constants, three damping constants, and an activation factor that varied from trial to trial. Parameters were optimized locally and globally using a high-performance computer. Muscle length and activation are the model inputs, and force is predicted in each time step. Results show that the model accurately predicts in vivo forces during perturbed and level gaits (average R2 = 0.67-0.88). Data and simulations show that force is related, not to onset or amplitude of EMG, but rather to: 1) onset and magnitude of the stretch that occurs when the foot hits the ground during active shortening; and 2) muscle length at ground contact. Results demonstrate how adding titin can improve prediction of in vivo forces during running over level terrain as well as when negotiating obstacles, and also suggests that some muscles depend on small stretches during active shortening for force production.

P1-102 WIBBELS, T*; NAVARRO, E; MANTANO, J; ROSAS, M; MARIN, G; BONKA, A; LOPEZ, M; ACOSTA, H; ILLESCAS, F; PENA, LJ; BURCHFIELD, P; Univ. of Alabama at Birmingham, Gladys Porter Zoo, Brownsville, TX, Univ. of Alabama Birmingham, CONANP, Ciudad Victoria, Tamaulipas, Mexico, CDEN, Ciudad Madero, Tamaulipas, Mexico; *twibbels@uab.edu*

In-water Movements and Arribada Nesting Behavior in the Kemp's Ridley Sea Turtle Using Preprogrammed UAV Surveys During the 2018 Nesting Season

The Kemp's ridley (*Lepidochelys kempii*) exhibits pan-specific migration behavior followed by mass nesting behavior (i.e. arribada behavior. In the current study, UAV-based aerial surveys using preprogrammed flight plans were used at the Kemp's ridley sea turtle's primary nesting beach at Rancho Nuevo, MX. Several different commercially available UAVs were used in the study using preprogrammed flight plans. Over 200 missions were flown during the 2018 nesting season. The results indicate that turtles gradually moved closer to shore several days prior to arribada nesting, and some relatively large in-water aggregations were recorded. The locations of the in-water aggregations as well as the locations of the arribada nesting was variable. The results also indicate that several days immediately prior to arribada nesting, turtles could move very close to shore and aggregate in the surf zone and adjacent waters. The in-water as well as nesting behaviors suggest that the turtles may be using specific aggregation cues and or nesting cues (e.g. social, environmental, etc.) to select aggregation and nesting locations. Collectively the results provide basic insight on migratory and arribada nesting behaviors in the Kemp's ridley sea turtle. This research was conducted as part of the ongoing Kemp's Ridley Bi-National Conservation Program.

P1-212 WICKER, VV*; BORUM, EM; BUGAY, MJ; CHEBLI, GY; PASCH, HN; POPSUJ, SE; ROOT, KM; SANTIAGO, TE; SAYRE, GE; SOTELO, J; TAYLOR, LEA; LEVIN, II; Agnes Scott College; *vwicker@agnesscott.edu*

Effects of Prescription Grazing on an Urban Forest Fragment Invaded by English Ivy (Hedera helix)

In urban areas, nonnative plant species often dominate forest fragments and reduce the biodiversity of these areas by altering species interactions and abiotic conditions. The removal of nonnative plants can benefit the community, but different removal methods, as well as legacy effects, can influence plant community restoration. Prescription grazing practices have been used to control nonnative plant species, but the impacts of grazing on plant communities have not been well characterized. In this study, we applied a grazing treatment in an urban forest fragment heavily invaded with English ivy (*Hedera helix*). Twenty-four goats (*Capra aegagrus hircus L.*) grazed in two fenced areas for eight days each. These grazed sites, as well as two control sites, were surveyed via permanent transects for changes in ivy cover, species richness, and abundance of native and nonnative plants before grazing, 2.5 weeks after grazing, and 9.5 weeks after grazing. Grazing reduced ivy cover in the short term, but this effect is not predicted to last in the long term; one grazed site was already indistinguishable from the control sites 9.5 weeks post-grazing. There was no observed difference in species richness or abundance by treatment between grazed and control sites. Our results indicate that grazing by goats is effective for reducing ivy cover, but full restoration of this forest will require the use of other methods to combat invasive plant species and increase the abundance of native species.

29-3 WILBER, MQ; CHINN, SM*; BEASLEY, JC; PEPIN, KM; National Wildlife Research Center, USDA & Colorado State Univ., Univ. of Georgia, National Wildlife Research Center, USDA; *sarahchinn@uga.edu*

Selection for agricultural crops predicts space use of a rapidly expanding invasive species in North America

Invasive alien species (IAS) can have significant ecological and economic impacts upon invading new habitats by substantially altering ecological interactions and ecosystem-level processes, and cost billions of dollars through impacts to agriculture, infrastructure and human health. Wild pigs (*Sus scrofa*) are one of the most successful and detrimental IAS, worldwide. As ecological generalists, they quickly adapt to new environments within their introduced range. We used an extensive GPS database of wild pig movement across the U.S., continuous-time movement models, and resource selection functions to address use and selection for agricultural resources and assessed how the availability of non-agricultural resources on a landscape affected the use of and selection for agricultural resources. At the home range scale, pigs used the most abundant crop type in proportion to its availability, and increased canopy cover decreased the amount of time spent in agricultural resources. Within-home range, presence of crops affected movement trajectories and varied by time of day where pigs tended to move toward crops in the evening and away in the morning. Wild pigs also traveled more slowly in areas of high canopy cover and were most likely to select for crops during peak planting and harvesting periods, and selected for crops less often when non-agricultural resources were abundant. Our results provide the first large-scale evidence that wild pig crop-use predictably changes with the availability of non-agricultural resources across spatial scales. Accurate estimates of agricultural crop-use can improve projection of crop damage and aid in predicting resource-use and movement across a large landscape, especially in terms of population expansion.

98-4 WILBUR, SM*; KITAYSKY, AS; BARNES, BM; WILLIAMS, CT; Univ. of Alaska Fairbanks; *smwilbur2@alaska.edu*
Tissue-Specific Telomere Dynamics in Hibernating Arctic Ground Squirrels (Urocitellus parryii)
Hibernation is a strategy used by some mammals to survive in the face of resource scarcity and is thought to confer increased longevity. However, reactive oxygen species (ROS) released in some tissues during periodic rewarmings may induce oxidative damage and accelerate cellular aging, which presents a life-history trade-off in hibernators. Telomeres, or the dynamic end-caps of chromosomes, can shorten in the presence of ROS, and an individual's telomere length may reflect the degree of accrued oxidative damage. The objective of this study was to determine telomere length dynamics throughout the hibernation season in arctic ground squirrels (*Urocitellus parryii*). We hypothesized that telomere shortening would be most pronounced in tissues that support arousal episodes. DNA was extracted from liver, heart, and brown adipose tissue (BAT) of 46 individuals sampled either at the middle or end of hibernation. qPCR was used to determine relative telomere length (RTL) for each tissue. Sex or age (juvenile vs. adult) did not affect telomere length in any tissue measured. In juvenile females, RTL in BAT was significantly shorter at late hibernation than at mid-hibernation, whereas RTL in liver and heart were not different between hibernation stages. BAT is the organ that generates heat during periodic rewarmings throughout hibernation. With BAT-associated thermogenesis comes a substantial increase in ROS, which may be shortening telomeres in this tissue. This study uses a multiple-tissue approach to address the life-history trade-off between longevity and cellular aging in a hibernating mammal.

P3-40 WILCOX, SC*; CLARK, CJ; Univ. of California, Riverside; *swilc002@ucr.edu*
Individual Variation in Flight Performance during a Hummingbird Courtship Display
Males of many animal species have evolved elaborate morphological ornaments and behavioral displays to attract the opposite sex. Some courtship behaviors seem challenging to perform and thus may serve as a means by which females judge male quality. In particular, locomotor performance during display could be tied to aspects of survival and genetic quality that may be of interest to choosy females. Black-chinned Hummingbird (*Archilochus alexandri*) males perform a repetitive side-to-side aerial "shuttle" display for females during which wingbeat frequency is nearly doubled and acceleration can be high. We examined individual differences in shuttle-display and burst-flight performances to test the hypothesis that individual variation in burst-flight performance is correlated with variation in shuttle-display performance. A significant link between shuttle-display performance and burst-flight performance would support the hypothesis that the shuttle display functions to signal male quality.

133-1 WILCOXEN, TE*; WEBER, R; ZIMMERMAN, LM; Millikin University, Millikin University ; *twilcoxen@millikin.edu*
Effects of Elevated Corticosterone on Immune Response to Aeromonas hydrophila in Northern Leopard Frog Tadpoles
Stress is known to have far-reaching effects on vertebrate immune defenses; however, it remains unclear to what extent stress hormones, such as corticosterone (CORT), influence different components of immune defense in larval amphibians. The purpose of this study was to identify whether exogenous CORT has an effect on innate and acquired immunity of Northern Leopard Frog tadpoles, Lithobates pipiens, when exposed to an opportunistic pathogen, *Aeromonas hydrophila*. We hypothesized that by elevating CORT, the tadpole immune defenses would be altered. In order to test innate and acquired immunity within the tadpoles, we conducted two experiments. In the first experiment, we exposed one group to exogenous CORT and maintained a control group without exogenous CORT, with neither exposed to A. hydrophila. In the second experiment, we exposed all tadpoles to *A. hydophila*, but again only exposed one group to exogenous CORT. We used a bacteria killing assay to assess innate immunity and an *A. hydrophila* ELISA to measure IgM and IgY antibodies generated in an acquired immune response. We found that the CORT dosed tadpoles killed significantly more *A. hydrophila* than the control tadpoles. Conversely, tadpoles dosed with CORT for an extended period of time had significantly lower plasma IgM and IgY against *A. hydrophila*. Our findings suggest that stress has differential effects on innate and acquired immunity in larval Northern Leopard Frogs similar to that seen in adult frogs.

32-2 WILGA, C*; DITSCHE, P; JACKSON, P; NATEKIN, E; FERRY, L; DUMONT, E; University of Alaska Anchorage, Arizona State University, University of California Merced; *cwilga@alaska.edu*
The Function Of Tessellated Cartilage In Shark Jaws
Sharks routinely feed on prey that have bony parts, yet the jaws and support structures are composed of cartilage. However, the cartilage of shark jaws is unique in being tessellated: mineralized blocks of cartilage interconnected by ligaments surround the inner core of hyaline-like cartilage. Tessellated materials are thought to resist fracture while stiffening the element and still allowing flexion compared to non-tessellated elements. Here, we tested the jaw and hyoid cartilages of several shark species in compression to determine if mineralization and stiffness varies by diet, feeding mode, and jaw suspension. The level of mineralization, as measured by percent mineralization of the cross-section of the area tested, is greater in the upper and lower jaws than the hyoid cartilages (hyomandibula, ceratohyal). The cartilages become stiffer when tested with increasing compressive load in a material testing system, as theorized in the literature. Not surprisingly this change in stiffness as measured by Young's Modulus is greater in the jaws than in the hyoid elements and also increases with greater mineralization. Stiffness and mineralization in the cartilages also varies by jaw suspension type and feeding style. A complicated relationship exists between cartilage stiffness and shape that appears to allow the jaws of sharks to bend slightly around prey that is harder than the jaws. In-vivo jaw cartilage strain varies by an average of 10% indicating that the jaws do bend around objects placed in the mouth. This combination of stiffness and compliance appears to contribute to fracture resistance in the jaws of sharks.

66-3 WILLIAMS, CT*; CHMURA, HE; GLASS, TW; Univ. of Alaska Fairbanks; *ctwilliams@alaska.edu*

Biologging physiological and ecological responses to climate change

Global climate change is rapidly affecting ecosystems world-wide by altering species' ranges, disrupting trophic interactions, and, in some cases, causing population declines. As such, there is widespread interest in developing new methodologies that will facilitate studies of climate change responses across taxa. In this talk, we will discuss studies of phenology, thermal biology, and microhabitat selection, and show how the use of biologging in this research is improving our ability to understand and forecast species' responses to climate change. One advantage of the biologging approach is that it can facilitate the measurement of traits at the level of the individual, permitting research that investigates how physiological and behavioral plasticity mitigates the negative consequences of climatic variation. We advocate for increased use of biologgers in climate change research, and increased biologging in experimental manipulations, to document and understand species' responses that may otherwise be difficult to study.

P2-269 WILLIAMS, KL*; EVANS, KM; SIMONS, AM; University of Minnesota; *will5761@umn.edu*

A model for tooth replacement and tooth function in a terrestrial fish, Alticus arnoldorum (Blenniidae)

The goals of this study are to **1)** establish a model of functional tooth replacement in a terrestrial blenniid, *Alticus arnoldorum*, exhibiting extreme tooth detachment from the jaws; **2)** demonstrate that classical descriptions of tooth attachment in combtooth blennies are inadequate to describe tooth function. The process of tooth replacement across most osteichthyan fishes has been well-described. Tooth replacement in osteichthyans occurs either in sockets within the bone of attachment (intraosseous) or within the soft tissue that surrounds the bone of attachment (extraosseous). In nearly all fishes, replacement teeth form into functional teeth that become anchored to the bone of attachment. Multiple lineages within the combtooth blennies (Blenniidae: Teleostei) serve as exceptions to these observations, as they exhibit functional teeth loosely attached to the bones of the jaw, or weakly attached via loose connective tissue and extending beyond the margins of the jaw bones. Combtooth blennies also occupy a wide range of habitats that span subtidal to supralittoral zones. Although several studies on habitat, diet and feeding behavior across Blenniidae have been conducted, descriptions of tooth development and tooth function in these fishes are limited to classical external observations. We describe tooth replacement using techniques that include staining and clearing, histology, and micro-CT scanning. The results of our study will expand upon current knowledge of the modes in which teeth are developed and replaced in osteichthyan fishes. In addition, our study will provide insight into how *A. arnoldorum* uses its oral teeth to feed in a novel terrestrial habitat.

15-3 WILLIAMS, SD*; PATTERSON, MR; Northeastern University; *williams.sar@husky.neu.edu*

Resistance and Robustness of the Global Coral-Symbiont Network

Warming induced coral bleaching is a major environmental stressor occurring on reefs. The coral holobiont, the coral host and its associated microorganisms, is a unique, complex system of symbiotic interactions that can be represented as a network. We have determined the global coral-*Symbiodiniaceae* network's resistance to temperature stress by developing a model to simulate an environmental "attack" (warming) on the network. Interactions (links) between coral species and algal symbionts (nodes) are weighted by considering individual thermotolerances and creating a combined threshold for each association. As temperature increases, links are removed when their threshold is surpassed. A coral is considered bleached when it has no more links. Resistance to temperature stress was determined from the response of the network to the bleaching model. Warming caused network breakdown in ways that differed from randomized networks, supporting that network structure and specific thermotolerances affect temperature stress resistance. Ecological robustness, how much perturbation is needed to decrease a network's nodes by half, was determined for multiple link and node removal models. Networks were more robust to link removals than to node removals. Of the link removals, removing links according to the bleaching model resulted in the lowest robustness. Natural networks will maintain a higher level of stability under environmental stressors compared to random networks, because of their interactions, unless those interactions are susceptible to a certain stressor, as is the case for coral reefs. The global network of coral-*Symbiodiniaceae* interactions and their associated thermal thresholds is non-random, and this architecture leads to a higher sensitivity to environmental perturbations.

138-5 WILLIAMSON, CJ*; SPELT, A; WINDSOR, SP; University of Bristol, UK; *cara.williamson@bristol.ac.uk*

Energy Saving Flight Strategies of Urban Gulls

The city is a complex environment to navigate as a bird; the wind interacts with buildings and other urban infrastructure to create areas of strong up- and down-drafts. During the breeding season, urban nesting gulls spend 40% of their time in flight, flying to and from foraging locations through these complex wind-scapes. Choosing appropriate flight paths has the potential to substantially reduce their energetic flight costs which could be key for breeding success. We used GPS backpacks to track 11 Lesser Black-backed Gulls (Larus fuscus) over two breeding seasons in the city of Bristol. The loggers collected a GPS fix and a one-second burst of 20 Hz three-axis accelerometer data up to every 4 seconds, allowing us to measure the flight paths of the gulls and characterise their flight modes. Meteorological forecasting data and machine learning techniques were used to identify the most commonly used flight strategies and associated environmental predictors. It was found that the gulls used a combination of orographic soaring and thermalling strategies; adapting their flight paths in response to local conditions to make energy savings of up to 66%. Computational fluid dynamics models of the wind in the city were then used to characterise the complex aerodynamic environment available to the gulls, and path planning optimization techniques were used to understand the potential energetic savings available to the birds and to investigate the trade-offs involved between energy expenditure and flight time. There is potential for using these flight strategies in the design of path planning algorithms for small unmanned air vehicles operating in similar environments.

30-6 WILLIS, SC*; CHANG, BSW; ROCHA, LA; California Academy of Sciences, University of Toronto; *swillis4@gmail.com*

Sexy red fish in the deep blue see: photosensory evolution across depth in sexually dimorphic coral reef fishes

Gene expression and coding sequence changes both facilitate adaptive evolution at the molecular level, but to what extent? Because the functional significance and mechanistic pathways are relatively well understood, phototransduction is an excellent domain to test the patterns of molecular adaptation and their import to diversification. Among vertebrates, coral reef fishes are known for their hyperdiversity, but there is a clear juxtaposition between lineages inhabiting shallow euphotic reefs and those from deeper mesophotic habitats, which differ in the prevailing light intensity and spectrum. Phylogenetic data show that repeated transitions between habitats have occurred, suggesting that depth drives diversification in reef fishes. Intriguingly, the Athiadinae or anthias fishes, which are very common and colorful inhabitants of shallow reefs, also includes many mesophotic species which are similarly colorful and sexually dimorphic in the red-yellow hues that are reduced in the blue-dominated spectrum at these depths. By analyzing RNA-seq data from the eyes of two mesophotic and two euphotic non-sister lineages of *Pseudanthias*, we determined that adaptation to spectral environment included both expression and coding changes in opsin genes: deep and shallow lineages preferentially express different paralogs of the green-sensitive Rh2 genes, while the constitutively-expressed blue-sensitive SWS2B gene exhibited parallel differences in codon positions that likely cause differences in spectral sensitivity. We will also discuss the relevance of these changes to patterns of biofluorescence in anthias fishes.

P3-102 WILLIS, SC*; WINEMILLER, KO; ROCHA, LA; WILLIS, Stuart; California Academy of Sciences, Texas A&M University; *swillis4@gmail.com*

Osmoregulatory evolution in freshwaters: Juxtaposition of differentially expressed genes and outlier loci of an Amazon cichlid in contrasting pH and ionic environments

Freshwater habitats of the Neotropics exhibit a gradient from neutral, relatively ion-rich whitewater to acidic, ion-poor blackwater. Closely related species often show complementary distributions among ionic habitats, suggesting that adaptation to divergent ionic environments may be an important driver of Neotropical fish diversity. However, little is known about the evolutionary tradeoffs involved in osmoregulation across distinct freshwater environments. First, we surveyed gill mRNA expression of a Neotropical cichlid that inhabits both environments, *Cichla ocellaris var. monoculus*, in laboratory conditions mimicking whitewater and blackwater. Gene ontology enrichment indicated that the gills were remodeled during both forms of environmental challenge, with changes biased towards the cellular membrane. Differential expression of genes related to paracellular tight junctions and transcellular ion transport showed responses similar to euryhaline fishes in fresh versus seawater. Second, we performed a population genomic survey using ddRAD markers of populations in different habitat types. These data confirmed previous results from microsatellite markers: strong population structure not strictly correlated with habitat type, indicating recent gene flow or co-ancestry across water chemistry in the central Amazon. Finally, using the Nile tilapia genome, we estimated the physical proximity of loci strongly divergent across habitats and differentially expressed genes to identify loci most critical in facilitating osmoregulatory adaptation. We discuss why these approaches may emphasize different genomic regions.

114-6 WILNER, D*; GREENWAY, EV; CIRINO, LA; MILLER, CW; Univ. of Florida; *danielawilner@ufl.edu*

Environmental Effects on Behavior and Fitness: The Impact of Temporary Nutritional Deprivation on Future Reproduction in the Leaf-footed Cactus Bug (Narnia femorata)

Environmental conditions can have strong effects on an organism's development, morphology, and fitness, often eclipsing the effects of genotypic variation. Diet, in particular, is known to have remarkable impacts on morphology and behavior across taxa. We investigated the impact of natural variation in seasonal diets on reproductive behavior and success, using the leaf-footed cactus bug (*Narnia femorata*), a hemimetabolous insect that feeds on a seasonally fluctuating resource. When seasonal variation causes a period of poor nutrition to coincide with a critical stage of development, how does it affect future reproduction? Newly eclosed adult females were allowed to mature on one of two, naturally occurring, seasonal diets, providing either excellent or poor nutrition (cactus with or without fruit). Then, after approximately 2 weeks (the age at which these insects typically become sexually mature), they were each provided excellent nutrition and a potential mate. We observed mating behavior (receptivity and mating duration) for three hours, and we then quantified fecundity (number of eggs laid) and fertility (eggs hatched) for 32 days, as well as obtaining female and male morphometric data. Preliminary analysis suggests that diet did not impact a female's likelihood to mate, nor the proportion of her eggs that were viable, but it did affect her reproductive output by impacting the number of eggs she laid. These results may have implications for the impacts of environmental change on behavior, fitness, and population growth.

P1-17 WILSON, AE; POLLACK, JL; BILLICK, I; DOMINGO, C; FERNANDEZ-FIGUEROA, EG; NAGY, ES; STEURY, TD; SUMMERS, AP*; Auburn University, NIH, RMBL, San Francisco State University, Mountain Lake Biological Station, University of Washington; *fishguy@uw.edu*

Structured Undergraduate Research Programs Make a Difference!

Training in science, technology, engineering, and mathematics (STEM) is a top priority for driving economic growth and maintaining technological competitiveness. We propose that exposure to a rigorous research program as an undergraduate leads to success in a research STEM career. We compared the scientific outcomes of 88 participants from five National Science Foundation Research Experiences for Undergraduates (REU) Site programs with demographically similar applicants to assess the impact that formal, organized, and funded undergraduate summer research experiences have on participants. Our study demonstrates that REU participants are more likely to pursue a PhD program and generate significantly more valued products, including presentations, publications, and awards, when compared with applicants. We believe that key components of the program include funding for personal and professional needs; access to diverse intellectual, analytical, and field resources; and the presence of other undergraduate researchers who support each other and share their goals and interests.

P2-171 WILSON, LE*; CURLIS, JD; LONSDALE, G; COX, CL; Georgia Southern University, University of Michigan, Operation Wallacea, GSU; *lw16271@georgiasouthern.edu*

Predator-based selection on coral snake mimicry components in the tropics

Studying the evolutionary drivers of aposematism and mimicry is crucial for understanding the origins of phenotypic diversity. In particular, understanding how selection acts upon the signal components of mimicry can give insight into how and where mimicry will arise. Our research focuses on coral snake mimicry, where brightly colored and venomous coral snakes are imitated by harmless snakes. Previous research found that components of coral snake color pattern must be precise in edge sympatry, may be relaxed in deep sympatry, and may not convey a fitness advantage at all in allopatry. However, this research has focused on species-poor temperate systems, and thus we know relatively less about the evolution of signal components in the diverse tropics. We tested which mimetic signal components are important for deterring predation in sympatry and allopatry with coral snakes in a tropical cloud forest in Honduras. We placed plasticine models that were 1) brown 2) white and black 3) red and black 4) white, red, and black (mimetic) in habitats that were both sympatric and allopatric with coral snakes. We found that while overall attack rates on models were similar among localities, predatory attacks by birds, but not mammals, were highest at the two low elevation localities. While overall attack rates were similar among all models, models with either bands or red color were attacked with less frequency by birds, but not mammals, than other models at one low elevation site. These results lend insight into how geographic range and predator assemblages may alter selection for signal components of coral snake mimicry systems in the tropics. Ultimately, this work highlights the processes that generate and maintain phenotypic diversity.

123-5 WILSON, RS*; AMIR ABDUL NASIR, AF; CAMERON, S; VON HIPPEL, F; University of Queensland, Northern Arizona University; *r.wilson@uq.edu.au*

Manganese contamination affects the motor performance of wild northern quolls

Neuromotor deficits are one of the first signs of manganese (Mn) toxicity in humans and laboratory animals. However, the impacts of Mn exposure on the motor function of wild animals remains largely unknown. Here, we assessed the impact of chronic exposure to Mn from active mining operations on Groote Eylandt, Australia on the motor function of the semi-arboreal northern quoll (Dasyurus hallucatus), an endangered species. The three motor tests conducted—maximum sprint speed on a straight run, manoeuvrability around a corner, and motor control on a balance beam—showed that elevated Mn body burden did not diminish performance of these traits. However, quolls with higher Mn body burden approached a corner at a significantly narrower range of speeds, due to a significantly lower maximum approach speed. Slower speeds approaching a turn likely reduce success at catching prey and avoiding predators. Given that maximum sprint speed on a straight run was not affected by Mn body burden, but maximum speed entering a corner was, slower speeds approaching a turn may reflect compensation for otherwise impaired performance in the turn.

P2-173 WILSON, E*; BARTS, N; COFFIN, J; KELLEY, J; TOBLER, M; GREENWAY, R; Kansas State University, Washington State University; *libbywilson719@gmail.com*

Comparative Analyses of Gene Expression Responses to Variation in Salinity across Distantly Related Fish Species

Transitions between marine and freshwater environments drive osmoregulatory adaptations of many aquatic organisms. Bidirectional transitions have occurred repeatedly during the diversification of fishes, allowing for broad scale examination of repeatable patterns in evolution. We are comparing genome-wide patterns of gene expression across six distantly related species pairs from high and low-salinity environments, including South American silversides (*Odontesthes*), scaleless carp (*Gymnocypris*), ide (*Leuciscus*), stickleback (*Gasterosteus*), killifish (*Lucania*), and livebearers (*Limia*). For each pair, we mapped raw reads to a close reference, identified orthologous genes, and compared the expression levels in an explicit phylogenetic framework. Identifying convergent patterns of physiological responses across distant lineages sheds insight about conserved mechanisms underlying osmoregulation in fishes.

P2-163 WILSON, AM*; MELICHER, DM; BOWSHER, JH; RINEHART, JP; North Dakota State University, USDA - ARS; *amanda.wilson.1@ndus.edu*

Effects of fluctuating temperatures on the longevity and fecundity of Drosophila melanogaster

Reduced temperatures have shown to increase the longevity of cold-tolerant insects. Insects that are not cold-tolerant experience elevated mortality when held at static reduced temperatures. A fluctuating thermal regime (FTR) has been shown to increase longevity and survivability in multiple insect species. During a fluctuating thermal regime insects are held at a reduced temperature with a one hour pulse of increased temperature each day. We measured the effect of FTR compared to constant temperature (CT) on the longevity and fecundity of Drosophila melanogaster held at CT-6°C, CT-22°C, and a FTR that oscillates between 6°C and 22°C. We demonstrate that a fluctuating thermal regime which oscillates between the cold and warm static temperatures greatly increases longevity with mean survival approximately seven times as long as other treatments and up to 241 days. We assessed the effects of FTR on male and female fecundity at 20-day intervals from 20 to 100 days and fecundity in the subsequent generation. Under the FTR treatment the fecundity of both JW and Oregon-R female flies declined steadily but after 60 days when no CT-6°C flies remained alive the fecundity of both strains remained at approximately 53% of control. Male flies of both strains exhibited an increase in fecundity under FTR peaking at 80 days before dropping significantly after 100 days. The reduction in female fecundity is likely a combination of the high cost of egg production and adult flies not consuming FTR culture media, while the increase in male fecundity remains unexplained. Offspring reared from each treatment group did not exhibit the patterns found in FTR parents.

97-6 WILSON, RC*; LEMASTER, MP; LUTTERSCHMIDT, DI; Portland State University , Western Oregon University, Portland State University; *rwilson@pdx.edu*

Leptin promotes reproductive behavior in red-sided garter snakes (Thamnophis sirtalis parietalis)

The endocrine mechanisms that mediate to what extent an individual invests in reproduction are poorly understood. Because reproduction is an energetically expensive activity, a hormone indicating accurate energy stores is a likely candidate for regulating reproductive investment. In numerous mammalian species, leptin accurately indicates fatty acid stores and influences reproductive hormones and behavior. To determine if the role of leptin is conserved across taxa, we injected red-sided garter snakes (*Thamnophis sirtalis parietalis*) with recombinant mouse leptin and measured reproductive behavior. We injected females with 0, 7, or 70 µg of leptin once a day for three days. Because female snakes become unattractive upon mating, females were subjected to a single mating trial. Male snakes were injected with 0, 3, or 30 µg of leptin once a day for three days and then subjected to a mating trial each day. We scored female and male mating behavior using ethograms. Although exogenous leptin did not affect female receptivity score, it significantly increased the proportion of females that copulated. Of the females that copulated, leptin did not affect latency to copulate or the duration of copulation. In male snakes, we found that leptin increased both courtship score and the number of copulations a male performed. Leptin did not influence latency to copulate, duration of copulation, the order of mating, or copulatory plug mass in males. In summary, the effects of leptin may be sexually dimorphic: exogenous leptin increased consummatory reproductive behavior in females, whereas it increased both appetitive and consummatory reproductive behavior in males. These data implicate leptin as a possible hormonal mechanism regulating individual variation in reproductive investment.

27-7 WILSTERMAN, K*; ALONGE, MM; ERNST, DK; LIMBER, CA; TREIDEL, LA; BENTLEY, GE; UC Berkeley, Las Positas College; *kwilsterman@berkeley.edu*

A test of the energy limitation hypothesis: acute food restriction prevents sickness behavior but not the immune response in female zebra finches

When animals experience immune challenges, they often suppress a range of behaviors. This suppression of activities is termed sickness behavior and appears to be a ubiquitous response in controlled settings. However, when more than one physiological challenge is presented to an individual simultaneously, such as occurs in more natural settings, expressing sickness behavior may not always be advantageous. One hypothesis, the energy limitation hypothesis (ELH), predicts that animals simultaneously faced with an immune challenge and food restriction will suppress their immune response only once they reach a minimum threshold body mass. Experimental tests of the hypothesis are needed to support its utility. We challenged female zebra finches with immune activation (lipopolysaccharide (LPS) injection) alone or in combination with acute food restriction (FR) and compared behavioral and physiological measures of the immune response among these groups (VEH-only, LPS-only, LPS+FR and VEH+FR). Regardless of food availability, LPS injection elicited a similar immune response as measured via a bacterial killing assay (BKA). However, an increase in time spent resting (a typical sickness behavior) was only observed in LPS-only birds, whereas LPS+FR individuals were behaviorally indistinguishable from VEH+FR birds. Strikingly, LPS+FR females did not lose more mass that LPS-only birds, demonstrating that body mass was not the proximate signal causing the switch in behavior expression. Thus, our data do not provide clear support for universal utility of the ELH. Our data highlight the need for additional dimensions, including social and real-world environments, to be applied in the conceptual frameworks that predict and explain animal responses to environmental challenges.

S9-7 WINNIKOFF, JR*; WILSON, TM; BACHTEL, TS; FRANCIS, WR; BUDIN, I; THUESEN, EV; HADDOCK, SHD; Monterey Bay Aquarium Research Institute, The Evergreen State College, University of Southern Denmark, Odense, University of California, Berkeley; *jwinnikoff@ucsc.edu*

Combing Transcriptomes for Secrets of Survival in the Deep Sea

Hydrostatic pressure influences the physiology of deep-sea animals through multiple mechanisms, such as altering enzyme kinetics and increasing phospholipid membrane viscosity. The Ctenophora, or "comb jellies", have repeatedly colonized most of the water column, from sea level to ~7 km deep, where ambient pressure is about 700 atm. Consequently, we have chosen these animals as a system for studying biochemical adaptation to pressure in an evolutionary context. Here we discuss ways to identify molecular determinants of pressure tolerance by comparing the transcriptomes of 34 ctenophore species. These bioinformatic techniques can be applied to a variety of environmental parameters. Correlations of protein-coding sequence to habitat depth are probed functionally through a cloning/reciprocal mutagenesis experiment in which ctenophore pyruvate kinase orthologs are expressed and assayed over a 900-atm pressure range. We also present a phylogenetic comparative analysis of fatty acid composition in ctenophores vis-a-vis regulating membrane viscosity at high pressure, and search for transcriptomic signatures of this critical biochemical trait. Our immediate objective for the approaches presented is to characterize the scope of convergent evolution in ctenophores: When lineages adapt independently to a similar habitat, does homoplasy appear at the scale of metabolic pathways? Of genes? Of individual amino acid sites? More broadly, our methods are intended to have utility for any investigator exploring mechanisms of extreme environmental tolerance though related species' transcriptomes.

P1-139 WINTERS, TJ*; LUTTERSCHMIDT, DI; Portland State University; *treven@pdx.edu*

Low-temperature winter dormancy alters thyrotropin immunoreactivity in the pituitary pars tuberalis of garter snakes.

The synchronization of physiology and behavior with favorable environmental conditions is tightly linked to an animal's fitness. This synchronization depends on an organism's ability to transduce environmental cues, such as photoperiod and temperature, into neuroendocrine signals that regulate physiological and behavioral processes. These neuroendocrine signals are critical to understanding the seasonality of vertebrate reproduction. Relative to photoperiod, however, there is comparatively little research on the potential role of temperature, despite the fact that many vertebrates (especially ectotherms) use temperature as a cue for timing seasonal mating. We hypothesized that temperature-activated reproduction is mediated by changes in thyrotropin synthesis within the pituitary pars tuberalis. We tested this hypothesis in red-sided garter snakes (*Thamnophis sirtalis*) using simulated winter dormancy, immunohistochemistry, and behavior assays. Field-collected snakes were hibernated at 4°C or 12°C in complete darkness and euthanized at 0, 4, 8, or 16 weeks in hibernation. Brains were collected and processed for thyrotropin (a.k.a. thyroid stimulating hormone, TSH) immunohistochemistry; we quantified the number of immunoreactive cells within a subregion of the anterior pituitary gland that is akin to the pars tuberalis. Our results suggest that TSH immunoreactivity in this pars tuberalis-like region changes in response to hibernation at 4°C for at least 4 weeks. Moreover, the observed changes in TSH mirror the effects of low-temperature dormancy on male courtship behavior. We suggest that TSH within the pars tuberalis can be modulated by environmental temperature, and these temperature-induced changes may in turn facilitate the effects of temperature on seasonal reproduction.

110-3 WITTMAN, TN*; COX, RM; University of Virginia; *tw9jj@virginia.edu*

Testing for fitness costs of parasitism in wild lizards (Anolis sagrei) with sustained-release formulations of the anti-parasite drug Ivermectin

Parasites interact with nearly all free-living organisms and can impose substantial fitness costs on their hosts. Accordingly, parasitism is predicted to be a significant selective force shaping the evolution of host phenotypes. However, studies testing this prediction are challenged by the difficulty of both measuring selection and achieving long-term manipulations of parasites in the wild. In particular, current anti-parasite drug formulations (1) are not well characterized for the non-model host species typically used in studies of selection, (2) are not commercially available at concentrations suitable for many of these species, and (3) require short-term dosing schedules that are incompatible with long-term sampling required to measure fitness. To address these challenges, we developed a method for the long-term removal of nematode and arthropod parasites from the brown anole, *Anolis sagrei*, a small lizard that is ideally suited for long-term studies of natural selection. First, we confirmed that oral delivery of Ivermectin, a broad spectrum anti-nematode and anti-arthropod drug, is effective at lowering nematode burden in captive A. sagrei. Next, we adapted techniques from the drug development literature to create a biodegradable, *in situ*-gelling injection for the sustained release of Ivermectin. We characterized the appropriateness of this compound *in vivo* over a period of four months in captive anoles. Finally, we tested this technique using a mark-recapture study of drug-treated and control-injected males (n = 70) and females (n = 85) to characterize the impact of nematode parasites on survival in a wild population of *Anolis sagrei*. While our work was done in *Anolis sagrei*, these techniques are generalizable and should allow for the long-term removal of nematodes and arthropods in a variety of host species.

8-6 WOELFER, J*; AMSON, EA; ARNOLD, P; BOTTON-DIVET, L; FABRE, AC; VANHETEREN, AH; NYAKATURA, J; Humboldt-Universitaet zu Berlin, Berlin, Museum fuer Naturkunde, Berlin, Friedrich-Schiller-Universitaet, Jena, Muséum national d'Histoire naturelle, Paris, Zoologische Staatssammlung Muenchen, Muenchen; *jan.woelfer@hu-berlin.de*

Does scaling of morphology depend on locomotor ecology? The case of the sciuromorph rodent femur

The scaling of morphology has been investigated for over a century. However, only a few studies have considered that the scaling effect might depend on the loading regime determined by the locomotor behavior of an animal. The sciuromorph rodents constitute an insightful object to investigate how the interplay of body mass and locomotion affects the postcranial morphology. Thy can be categorized into arboreal, fossorial, and aerial locomotor groups, each including a body mass range spanning two or three orders of magnitude. We analyzed univariate and multivariate (shape) femoral parameters for 139 out of approx. 300 species. PGLS regressions were used to test whether intercepts and slopes differ relative to body mass for the derived fossorial and aerial groups when compared to the ancestral arboreal one and whether all slopes differ from isometry. Most of the univariate parameters scaled with isometry, suggesting that scaling adjustments have not played a significant role for most of the femoral features. The sizes of the femoral head and condyles, the width of the patellar groove and the in-levers of the muscles attaching to the major and lesser trochanters displayed a lower scaling exponent in fossorial when compared to arboreal species. The shape of the lesser trochanter exhibited differences in scaling among locomotor groups, manifested in the orientation and protrusion from the shaft. We suggest that these femoral features had a functional significance during the ecological diversification of sciuromorph rodents.

102-3 WOLF, SE*; BELTRAN, SE; SANDERS, TL; ROSVALL, KA; Indiana University, Dominican University, Oklahoma State University; *wolfsae@indiana.edu*

When mom takes a sick day: sex-specific telomere dynamics in response to early postnatal stress

Early life stress can have long-term effects on many phenotypic qualities, including telomere dynamics. Telomeres are the guanine-rich, protective ends of chromosomes that shorten with accelerated growth and exposure to stressors, and prior work suggests that telomeres in male and female animals may differ in sensitivity to stress. Here, we tested how a mild maternal stressor influences offspring telomere dynamics during postnatal development in tree swallows (*Tachycineta bicolor*) and asked whether sex predicts the effects of stress on a suite of traits. Specifically, when chicks were 5 days old, we injected mothers with either saline or lipopolysaccharide (LPS), which elicits a 24h sickness response. In the week following treatment, we measured chick growth, telomere length, and restraint-induced corticosterone (CORT). We found that within 24h post-injection, LPS females decreased nest visitation rate, resulting in a short-term reduction in chick growth relative to controls. Consequently, telomere dynamics differed between treatments, and stronger effects were observed in males. Males from LPS nests also exhibited dampened stress reactivity (i.e. CORT elevation), which was positively correlated with telomere length, suggesting that changes in telomere length may be mediated by CORT. However, chicks from experimental and control nests did not differ in morphology at 12 days old, suggesting that stress-exposed chicks may carry cryptic physiological variation that could manifest later in life. While additional research is necessary to identify the mechanisms underlying these sex-specific patterns, our results provide novel insights into sex-specific vulnerability to early-life stress.

64-5 WOLF, Z.*; VOGT, D.; LAUDER, G.V.; Harvard University, Wyss Institute; *zwolf.mlxvi@gmail.com*

Studying fish locomotion using a multi-segmented soft robotic, pneumatically-actuated model

Previously at SICB, we introduced the "pneufish," a soft robotic fish model with two actuators (pneunets) attached to a flexible passive foil. Pneunets consist of a series of connected, segmented chambers molded from silicone rubber, 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 via programmed digital pressure regulators. Assembled pneufish were suspended in a recirculating flow tank, attached to an ATI 6-axis force-torque sensor, and we measured thrust, lateral forces, and the amplitude of trailing edge oscillation during locomotion. Pneufish were activated pneumatically using a large range of parameters, focusing on frequency, water flow speed, maximum and minimum air pressure, and foil stiffness. Results showed strong interactions between stiffness and frequency, while frequency on its own had a rather small effect on performance. We then expanded the pneufish model to include four pneunets, arranged in pairs sequentially down the foil, to make the "quad pneufish" model. Using this quad pneufish apparatus, we continued to investigate the model's performance across a parameter space, adding activation phasing, differential air pressure between front and back pneunet pairs, and the effect of pneunet orientation on the model's performance. These additional parameters allowed us to investigate the performance of different activation patterns in a more complex biomimetic fish-like model, allowing the quad-pneufish apparatus to be used as a model for investigating the effect of different patterns of body deformation on aquatic propulsion.

P3-67 WOLF, CJ*; SASSER, KT; SENNER, NR; CHEVIRON, ZA; Univ. of Montana, Univ. of South Carolina; *colejwolf@gmail.com*
Landscape Genetics 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.

59-3 WOLFF, GH*; RIFFELL, JA; Univ. of Washington; *gabwolff@uw.edu*
Smell-O-Vision: Functional Imaging of Odor-Evoked Activity and Neuromodulation in the Mosquito Antennal Lobe
Mosquitoes primarily use olfaction to seek out host animals or plants and they can remember odors associated with positive or negative experiences. However, which odors can be learned differs from species to species. Those odors associated with a preferred host may be learned more readily than less salient odors. Since anatomical neural circuitry of the olfactory system is highly conserved across mosquitoes, we hypothesized that neuromodulation by dopamine mediates species-specific differences in olfactory learning behaviors. We thus localized the dopamine precursor, tyrosine hydroxylase in the antennal lobes of four mosquito species: *Aedes aegypti, Toxorhynchites amboinensis, Anopheles stephensi* and *Culex quinquefasciatus*. Each species had a distinct pattern of dopaminergic innervation to the antennal lobes. Additionally, concentration of dopamine was markedly heterogenous across antennal lobe subunits called glomeruli. To understand the relationship between neuromodulation and olfactory learning, we used 2-photon calcium imaging in the brains of *Ae. aegypti* expressing gCaMP6 to record odor-evoked activity in the antennal lobes. Mosquitoes were stimulated with the odor chemicals 1-octen-3-ol, hexanoic acid, or linalool and we identified glomeruli tuned to respond to each odor. We then used quantitative immunohistochemistry to assay dopamine expression levels in the identified glomeruli. These results will be discussed in the context of mosquito performance in learning to associate each odor with an aversive stimulus in a classical conditioning paradigm. The effects of dopamine on olfactory learning in mosquitoes may have broader implications for uncovering general principals of olfaction and memory in insects and other animals.

97-1 WOLFORD, D.M.*; DAVIS, J.E.; Radford University; *awolford5@radford.edu*
Investigating the Effects of Juvenile Hormone and Royal Jelly on Lasiodora parahybana
Here I describe the results of an on-going study, in which we are investigating the interactive effects of major royal jelly peptides (MRJP) and juvenile hormone (JH) on growth, health and behavior in the salmon-pink bird eating tarantula (Lasiodora parahybana). Currently, there have been no studies to determine whether or not arachnids possess MRJP receptors. This study not only aims to explore that possibility, but also explores both the possibility of MRJP and JH interactions in arachnids and to determine the relationship between hormonal modulation, health, and overall behavioral traits. Along with physiological and morphological measures addressing health, growth, and anatomy, we also explore interactions and patterns describing behavioral syndromes related to proactive and reactive strategies, how they may vary within individuals and how they may be impacted by hormonal treatments.

P2-282 WOMACK, MC*; LEMMON, EM; LEMMON, AR; HOKE, KL; National Museum of Natural History, Florida State University, Colorado State University; *mollywo@berkeley.edu*
Signatures of Relaxed Selection Characterize Earless Toad Lineages
Here we integrated genetic, morphological, physiological, and developmental data to propose potential selection pressures contributing to convergent loss and potential regain of middle ear structures across the family of true toads (Bufonidae). Middle ear structures are shared by most tetrapods for hearing airborne sound, yet they have been lost at least eleven times in Bufonidae, despite the fact that frogs and toads are known to use acoustic communication for mate attraction and other conspecific interactions. Sequence analysis of coding regions in 60 bufonid species (16 earless, 44 eared) nominates six of 30 candidate genes known to be important for tetrapod middle ear development as possible contributors to middle ear loss. These six candidate genes exhibited relaxed purifying selection in earless lineages when compared to closely-related eared lineages. Earless lineages did not share any parallel amino acid changes or evidence for positive selection within coding regions associated with tetrapod middle ear development, complementing our lack of evidence for shared selection pressures acting on anuran middle ear loss in relation to ecology or pleiotropic skull trade-offs. The relaxed purifying selection associated with anuran middle ear loss provides an intriguing starting point for the investigating the genetic basis of anuran middle ear development in relation to better-known tetrapod groups. With this added genetic evidence, we further support the hypothesis that middle ears are lost by a combination of relaxed selection on the middle ear and changes in development rate.

74-1 WONG, S*; BIGMAN, JS; DULVY, NK; Simon Fraser University; *serenaw@sfu.ca*

The metabolic basis of life histories in fishes

All life acquires energy through metabolic processes, and then that energy is allocated to survival, growth, and reproduction. Thus, metabolic rate is thought to be closely related to life-history traits as it governs how energy is allocated among competing functions. Previous work suggests that life-history traits, such as somatic and population growth rate may explain some of the variation in the relationship of basal metabolic rate and body mass in endotherms. However, few studies have examined the relationship of metabolic rate and life-history traits in ectotherms. Here, we ask whether life history explains variation in metabolic rate. Specifically, we examined whether somatic growth rate, age at maturity, maximum size, and population growth rate were related to metabolic rate in 100 bony and 25 cartilaginous fish species while accounting for phylogenetic non-independence. Somatic growth rate and maximum size, and population growth rate were positively related to metabolic rate, while age at maturity was negatively related. Together, these traits explain significant variation in metabolic rate. Further, metabolic rate has strong phylogenetic signal, indicating that closely related species have more similar metabolic rates than more distantly related species. Understanding the physiological basis of life-history traits, which are difficult to estimate for data-poor and threatened species, has the potential to improve conservation and management efforts as life histories and especially population growth rates are closely correlated to extinction risk.

59-6 WOOD, T/C*; MOORE, P/A; Bowling Green State University; *tcwood@bgsu.edu*

Dietary Cues from Fish have Indirect Effects on Aquatic Plant Communities Mediated by Changes in Crayfish Behavior.

Many prey animals use olfactory cues for predator detection and will change their behavior to avoid the predator. The olfactory cues released by predators are unique mixtures of chemicals that are determined by the species of the predator, the predator's physical condition and diet. Some prey species can differentiate changes in the diet of the predator which may alter the prey's antipredator response. If different predator dietary cues lead to shifts in the foraging behavior of prey, then changes in predator diet could have indirect effects on the species on which prey forage. A tri-trophic interaction involving *Micropterus salmoides, Faxonius rusticus,* and three species of freshwater macrophytes (*Myriophyllum exalbescens, Elodea canadensis, & Chara* spp.) was used to test the hypothesis that differences in the diets of predatory fish can change crayfish foraging behavior and produce indirect effects in macrophyte communities. The predatory *M. salmoides* were fed four different diets consisting of commercial fish food, *F. virilis* crayfish, *F. propinquus* crayfish, and *F. rusticus* crayfish. Four *F. rusticus* were then placed into mesocosms with samples of each plant species and were allowed to feed while being exposed to odors from different predator diet treatments. The crayfish showed significant differences in plant consumption across the various predator diets. Different predator diets also changed the foraging preferences of the crayfish, causing them to feed selectively on different plant species depending on the predator diet treatment applied. These results demonstrate that prey animals are sensitive to predator dietary cues and that these cues can mediate indirect effects of predators on other species in aquatic communities.

P2-86 WOOD, M/N*; SOLTIS, J; Disney's Animal Kingdom; *michelle.n.wood.-nd@disney.com*

Measuring and Mediating Night Light at the Zoo

Light and light cycles produced by the sun have shaped the adaptations of animals on earth over millions of years. Artificial light produced by humans has imposed new sources of light that can profoundly impact animals. These impacts can be particularly strong on animals in managed care, where sources of artificial light compete with or replace natural light. Light exposure drives circadian rhythms and can affect multiple biological processes across all taxa including; sleep wake cycles, activity budgets, behavior, body condition, reproduction, immune function, digestive function, and much more. Disney's Animal Kingdom® has extended its operating hours resulting in artificial light sources illuminating animal habitats past natural sunset. With this in mind we began to measure light sources and mediate brightness and/or spectral distribution as appropriate. Our goals are to keep illuminance measurements in a range that would be typical at night, and reduce or eliminate wavelengths below 500nm (blue, violet, and UV wavelengths) which have the strongest impacts on circadian rhythms. We will discuss examples of mitigation techniques and their effectiveness.

P1-272 WOODRING, A*; ZIMMERMAN, M; LANDBERG, T; Arcadia University, Glenside; *awoodring@arcadia.edu*

Carry-over effects of larval hydroperiod and conspecific density on the phenotype and urban translocation success of American Toads (Anaxyrus americanus)

Urban translocation success of native species is often low because of habitat degradation due to invasive species, lack of phenotypic variability, and differences between source and release environments. We marked and released 327 American Toads (*Anaxyrus americanus*) raised under different experimental conspecific densities (10 or 29 tadpoles/tank) and hydroperiods (60, 75, or 90 days) to a 12-acre wooded suburban park with a manmade pond. Introduction success was expected to increase with body mass if selection was strongest against individuals vulnerable to resource deprivation (low moisture or food levels). Alternately, introduction success was expected to increase with jumping distance if selection was strongest against toads unable to escape predators by jumping. Time to metamorphosis was highest in the 75-day hydroperiod, with a greater effect at low density (significant hydroperiod*density interaction, ANOVA, $p=0.0017$). Body size (snout-vent length, leg length, and mass) at metamorphosis significantly increased with density (ANOVA, $p<0.0001$, $p<0.0001$, $p=.0052$ respectively). Survival rate through metamorphosis was highest in the higher density with a significant interaction between density and hydroperiod (ANOVA, $p= 0.0311$ and $p=0.0175$ respectively). Similar to our first (unsuccessful) introduction attempt of 670 toads in 2016, recapture success this year has been very low. Generating different phenotypes may increase introduction success, however, poor habitat quality, priority effects (green frog predation), and relatively low numbers for an introduction attempt still present difficulties in experimentally studying and restoring urbanized habitats.

P1-160 WOODRUFF, MJ*; HILL, HM; NOONAN, M; Indiana University, Bloomington, St. Mary's University, Canisius College; *woodrufm@iu.edu*

Individual Difference in the Behavior of Beluga Whales (Dephinapterus leucas)

The topic of individual differences in animal behavior has garnered a great deal of attention across many species, but questions remain as to whether behavioral differences change over time or across age and sex. The present study focused on beluga whales (*Delphinapterus leucas*), a species in which a high degree of behavioral variability may be expected due to the fact that belugas are large-brained, long-lived, and highly social in nature. We recorded a suite of 33 behavioral measures related to boldness, playfulness, sociability, and other traits, with the goal of assessing age and sex differences in behavior, as well as consistency within individuals over time. Our subjects were seaquarium-based, and mixed in age and sex (N=41). Findings showed that immature whales were rated as more spontaneous and more likely to be at the observation window, suggesting perhaps investigative behavior varies with age. Adult whales, on the other hand, were more likely to swim in non-standard body orientations, to display vigilant behavior, and to be rated as dominant. Most importantly, 22 of the 33 behavioral measures showed significant within-subject consistency over time, suggesting that stable behavioral differences appear to exist in this species (behavioral syndromes). However, very few measures showed significant correlations with each other, indicating that they could not be grouped into identifiable factors that comprised recognizable "personalities." Instead, we suggest that personality may be built in different ways depending on an individual's age, sex, and contextual variables that may influence the degree to which specific sets of behaviors co-vary.

26-6 WOODS, HA*; LARKIN, BG; DAHLHOFF, VC; Univ. of Montana, MPG Operations, LLC; *art.woods@mso.umt.edu*

Thermal ecology of small ectotherms in mosaics of plant-generated microclimates: aspens and aspen leaf miners

Small ectotherms live in microclimates, which can vary in complex ways in space and time. A key factor driving microclimatic complexity is irradiance—relative sunniness or shadiness. We examined how sun versus shade drives patterns of temperature diversity in aspen canopies (*Populus tremuloides*), and the consequences of those patterns for small, leaf-mining caterpillars (*Phyllocnistis populiella*). In particular, we evaluated whether exposure to direct sunlight (1) alters larval growth rates by systematically altering distributions of daytime temperatures; or (2) increases risk of mortality from short-term exposure to lethally high temperatures without significantly altering the overall diurnal distribution of temperatures. We distinguished these possibilities by experimentally shading leaves in the field and measuring effects on leaf temperature and on larval growth and survival. We also estimated larval thermal performance curves (for growth) using short-term, lab-based exposure to constant temperatures, and upper lethal temperatures in the field using custom-built, heat-shock devices. Our data suggest that intra-canopy variation in the position, orientation, and relative irradiation of leaves drives high levels of spatial and temporal variation in leaf temperature—but that the high temperatures reached by sun-exposed leaves are transient enough that they are more important in driving risk of exposure to lethal temperatures than they are in shifting larval performance within the permissive range of temperatures.

P2-9 WORLEY, CA*; NEBHUT, AN; SHINKLE , JR; Trinity University, San Antonio; *cworley@trinity.edu*

Long Term Effects of High Energy UV-B on Texas Native Grass Pigmentation and Structure

Plants have mechanisms to sense dangerous ultraviolet radiation and regulate their responses to changes in their light environment. In particular, plants exposed to UV-B (280 to 315 nm), which includes photons of the highest energy levels found in sunlight, display unique responses such as inhibited growth and production of UV-protecting pigments. These responses may be permanent or transitory. Persistence of plant responses to a reduction in UV radiation in field setting was studied as follows. Texas grasses were placed, in full sunlight, under two filters: aclar, which is UV transparent, and cellulose acetate, which blocks almost all energy at wavelengths shorter than 300nm. The immediate and long-term effects of high energy UV-B radiation on plant function were tested using UV absorbance spectra taken from leaf pigment extracts and reflectance spectrophotometry of leaves. Both spectra were taken three times for each test plot, once at the beginning of the experiment, once after the treatment period, and once after two weeks of recovery. Results from rural and urban field sites in addition to greenhouse studies support that exposure to UV radiation sometimes leads to changes in leaf structure and composition that can persist after treatment concludes. However, this result is not identical across species or field sites. For instance, the Bandera county sideoats grama (*Bouteloua curtipendula*) extracts exhibited lower absorption in the 300-320 nm band after treatment than before treatment, but for Travis county sideoats grama there were no differences between initial, treatment, and recovery absorbance readings. These results indicate that under different circumstances as yet unidentified, grasses of even the same species exhibit different responses to UV-B radiation.

P1-115 WORTHINGTON, S.E.*; HEWS, D.K.; Indiana State University; *smank513@gmail.com*

Colorful Ovoviviparous Lizards and Their Offspring

Female aggression and male-like coloration are not well-studied in squamate reptiles. Female *Sceloporus jarrovii* (Yarrow's Spiny Lizards) exhibit blue ventral colorations similar to males of the same species. The ovoviviparous females are aggressive towards one another, with a peak in aggression around the parturition season in May and June. We hypothesize that females are aggressive towards other females to (A) protect their offspring, (B) protect their food resources, or (C) establish new territories with food resources. We also hypothesize that female ventral coloration changes with gravidity status, hormone level, and size. This research focuses on the mechanisms leading to and functions of female coloration, aggression, and offspring phenotype. The offspring dispersal and birth characteristics for this species are not well-studied. Previous research has found changes in population levels of testosterone and corticosterone during the parturition season. We collected ventral images, morphological data, behavioral observations, and hormone samples from individually marked females before and after birthing their offspring in a semi-natural enclosure. For the purpose of this presentation, we focus on the maternal coloration and offspring dispersal behavior immediately following birth. Images of the ventral side of each female are analyzed using ImageJ software. Offspring dispersal characteristics are classified as proximity to mother over a given time period. Close proximity of the mother and her offspring over time indicates that aggression towards other adult females may be in defense of the offspring. Early separation of the mother from the maternal site and the offspring may indicate that the female leaves the successful territory to her offspring and disperses to find herself a new territory.

132-1 WRENSFORD, KC*; GUTIEREZ, JA; COOPER, WE; BLUMSTEIN, DT; Univ. of California, Berkeley, Univ. of California, Los Angeles, Purdue University Fort Wayne; *kwasi_wrensford@berkeley.edu*

. Does interpath angle Influence escape behavior: An empirical test with yellow bellied marmots.

Escape theory provides a critical conceptual framework for studying the effects of predation risk, including the effects of the costs of fleeing on flight initiation distance (FID), defined as the predator-prey distance at which escape is initiated. Economic escape models, however, have been limited to predictions based on individual factors, even though multiple factors may simultaneously affect prey escape decisions. The race-for-life model incorporates the effects of multiple risk factors to predict FID, including the speed, distance and direction to a refuge for both predator and prey. The inter-path angle (the angle between the paths of the predator and prey to the refuge) captures the effect of direction of escape on FID. To assess the role of inter-path angle on the escape behavior of yellow-bellied marmots (*Marmota flaviventris*), we documented escape responses by free-living members of this species in response to human activity. The race-for-life model's equation successfully calculated FID using data measured in the field. Our analyses revealed effects of inter-path angle on FID consistent with findings of previous studies. However, these effects were not consistent across contexts. These findings support the expectation that marmots take both distance and escape trajectory into account when assessing predation risk. Future studies involving diverse prey taxa will serve to assess the generality of the race-for-life model as a framework for understanding prey escape behavior.

S7-4 WRIGHT, Natalie A*; WITT, Christopher C; TOBALSKE, Bret W; Kenyon College, University of New Mexico, University of Montana; *nataliestudiesbirds@gmail.com*

Biomechanics of Flight Across the Avian Tree

Linking predictable, repeatedly observed evolutionary patterns in morphology to their functional implications is vital to understanding how and why those patterns have evolved. Here we use multiple datasets to link evolutionary changes in flight morphology to their ecological drivers and functional implications. We have found that across the avian tree, bird species restricted to islands tend to evolve smaller flight muscles and longer legs than their continental relatives. This predictable evolutionary pattern is strongest on small islands with fewer predators. The relaxation of predation pressure may lead to a shift to a Bauplan less suited for rapid takeoff. However, the precise functional implications of these morphological changes for takeoff and flight are not well known. We tested how these morphological differences affect flight performance using a novel comparative dataset of takeoffs for 16 species from five orders, ranging body size from 4.1g to 130g. Both across and within species, birds with larger flight muscles reached faster peak take-off velocities and exhibited a greater reliance upon the wings relative to the leg thrust during takeoff. We conclude that when island bird populations evolved smaller flight muscles and longer legs, it resulted in a shift toward leg-dominated take-off mechanics, reduced takeoff velocity, and reduced capacity to escape from predators.

4-6 WRIGHT, R*; NUTTALL , M; DAVIES, S; Harvard Medical School, Flower Garden Banks National Marine Sanctuary, Boston University; *rachelwright8@gmail.com*

Coral gene expression signatures of a mass die-off event in the Texas Flower Garden Banks

In July 2016, the pristine East Bank of the Texas Flower Garden Banks National Marine Sanctuary experienced unprecedented mass mortality of multiple invertebrate species, which caused highly localized reductions in coral cover. As part of a scientific team tasked with identifying the cause of the devastation, we collected gene expression samples from affected and unaffected coral colonies to determine the physiological consequences of the event on tissues from two congeneric coral species (*Orbicella franksi* and *Orbicella faveolata*) from both the East (affected) and West (unaffected) Banks. At the affected site, we preserved three types of tissue samples: apparently healthy colonies (no symptoms), affected colonies along the lesion of tissue loss progression, and healthy tissues from affected colonies (i.e., at least 30 cm away from lesion). Genome-wide gene expression libraries (N = 76) were prepared in-house and sequenced on the Illumina HiSeq 2500 platform. Both coral species exhibit similar gene expression patterns across tissue types. Apparently healthy tissues from affected colonies show no significant differences in overall gene expression compared to tissues from completely healthy colonies, but many genes are differentially expressed in the affected tissues relative to both healthy tissue types. Gene enrichment analysis suggests that affected coral tissues were experiencing oxidative stress and up-regulating genes related to mitochondrial processes, suggesting that hypoxia may have played a role in the mass mortality event on the reef. These data also highlight the diagnostic power of an affordable next-generation sequencing methodology using ecological samples.

48-3 WRIGHT, T.F.*; DERRYBERRY, E.P.; New Mexico State University, University of Tennessee Knoxville; *wright@nmsu.edu*

One Trait or Many: Reexamining the Multidimensional Nature of Vocal Learning

Vocal learning has evolved repeatedly and independently in several lineages of birds and mammals. This pattern of evolution begs interesting questions about both the selective advantages of this complex cognitive trait and the neurogenetic mechanisms that give rise to it. Vocal learning is commonly treated as a binary trait that species either possess or lack entirely. This binary view has been a useful starting place for examining the origins of vocal learning, and has furthered our understanding of the neuroarchitecture and gene expression specializations that are shared across vocal learning taxa like humans, songbirds and parrots. This binary framework is also misleading though, as specific components of the learning program - such as the timing, extent and nature of what is learned - vary widely among species. This variation led Brenowitz and Beecher (2005a,b) to argue that vocal learning should be viewed as a multi-dimensional trait in which different dimensions may be under different selective forces and governed by different mechanisms. They argued that such a framework would be particularly powerful when combined with a comparative perspective. Here we revive and expand this framework by describing six discrete dimensions of vocal learning and discussing evidence of variation in each within and across species. We then highlight several recent examples of work that focus on one of these dimensions and examine either evolutionary hypotheses explaining this variation or neurogenetic mechanisms that underpin it. We end by discussing how new tools and analytical approaches to test these hypotheses and highlight key areas in which a multi-dimensional framework, coupled with a comparative perspective, will rapidly advance our understanding of why and how vocal learning has evolved.

P2-106 WRIGHT, SK*; LAMBERT, FN; WOOD, MW; ALBA, A; FONTENOT, DK; WHEATON, CJ; Disney's Animal Kingdom®; *sarah.k.wright.-nd@disney.com*

Fecal Corticosterone Evaluation of Individual Potential Translocation Candidacy in Threatened Avian Species

Populations of avian species (e.g. golden white-eyes (GOWE), Mariana fruit doves (MAFD), rufous fantails (RUFA), and Tinian monarchs (TIMO)) in the Mariana island chain have declined since the regional introduction of the brown tree snake to Guam. Efforts to establish security populations of these species through collection and translocation to nearby islands have occurred via the Marianas Avifauna Conservation Program since 2004. Using a previously validated enzyme immunoassay, we measured fecal immuno-reactive corticosterone (B) in daily (24h total fecal output) samples from individual birds collected from mist nets (April-May, 2015-2018) and placed in a holding facility for health evaluation for up to two weeks before release. We observed considerable variation in fecal B on day of collection (=day 0) and day 1 in holding in all species, with most birds acclimating by day 2-3. GOWEs had the least amount of variation on day 0, highest variation on day 1, and took 1-2 days longer to acclimate. Some MAFDs and TIMOs had secondary B responses (days 3-5) attributed to concurrent health exams for recently collected birds added to the holding room. Individuals that sustained injury during collection, lost body mass during holding, or expired, exhibited a pattern of elevated B on day 0, 1, or the day of injury. Our results suggest that 1) most birds acclimated quickly to holding (>97%); 2) current management and husbandry strategies did not adversely affect health or mortality; and 3) fecal B can be used as a complement to disease and health assessment to help choose the best individuals for translocation. These methods have the potential to be applied to other avian species targeted for field conservation initiatives.

11-7 WRIGHT, MA*; PIERCE, SE; Museum of Comparative Zoology and Department of Organismic and Evolutionary Biology, Harvard University, USA; *markwright@fas.harvard.edu*

Functional Morphology of the Hip Joint during Mammalian Evolution

Mammals are a morphologically and ecologically diverse clade. They inhabit environments around the world from oceans to treetops and display a range of locomotory behaviors that includes running, climbing, swimming, and digging. In contrast to living mammals, the ancestors of mammals, non-mammalian "pelycosaurs", are traditionally reconstructed as simple terrestrial quadrupeds with limited ecological scope. The transition from "pelycosaurs" to mammals is characterized by a postural shift that greatly impacted locomotor behavior. The limbs of "pelycosaurs" were abducted to the side, and they moved with a sprawling gait, analogous to lizards and salamanders. The limbs of mammals, however, are positioned underneath the body and operate primarily in a parasagittal plane of motion. To understand how reorientation of the limbs during mammalian evolution impacted musculoskeletal function, we built virtual hindlimb models of two taxa, *Dimetrodon milleri* and *Monodelphis domestica*, to represent "pelycosaurs" and mammals, respectively. For each model, we determined hip joint range of movement in three orthogonal planes and estimated moment arms for all major muscles of the proximal hindlimb. Three functional differences were found in mammals compared to "pelycosaurs": increased flexion-extension range of motion, reduction of abduction-adduction moment arms, and acquisition of joint-stabilizing flexion-extension muscles. These functional changes are underpinned by a relative decrease in the width of the pelvis, bringing muscle origins closer to the hip center of rotation. Our findings demonstrate a structural change associated with multiple functions and illustrate how musculoskeletal reorganization led to dramatic shifts in locomotory behavior during mammalian evolution.

108-1 WROBEL, ER*; MOLINA, E; KHAN, NY; AKINGBEMI, BT; LORENZ, WW; MENDONCA, MT; NAVARA, KJ; University of Georgia , Auburn University, University of St. Andrews, University of Georgia; *ewrobel@uga.edu*

Responsiveness of the chicken germinal disk to testosterone and corticosterone

Female birds skew offspring sex ratios based on environmental and social stimuli, but the mechanism mediating these skews remains unknown. Growing evidence suggests that testosterone and corticosterone may influence sex chromosome segregation, as they skew sex ratios when experimentally elevated immediately before. It is unknown whether the germinal disk (GD) contains receptors for these hormones and whether any receptors present allow the GD to respond genomically to treatment with testosterone and corticosterone. We collected ovarian follicles at 5h pre-ovulation (just before chromosome segregation) and 20h pre-ovulation (when sex chromosomes are arrested), and measured androgen receptor (AR) and mineralocorticoid receptor (MR) protein levels via Western blot. ARs and MRs were present in both the GD and non-GD regions. AR protein levels were higher in the GD region than the non-GD region, but MR protein levels did not differ between regions. Next, we tested whether short-term treatment of hens with these hormones changed expression patterns of genes affecting meiosis. We had 3 treatments (n = 50 hens each): Injection of (1) 1.5mg T in 0.5ml of peanut oil (2) 1.5mg of CORT in 0.5ml of peanut oil, and (3) control oil injection, all at 5h before ovulation. We collected GDs from hens 1.5h after injection and, using RNA-sequencing, we identified 4 genes differentially expressed between the corticosterone and control group that are of interest. This work revealed that ovarian follicles contain receptors that respond to these hormones, and that these hormones may influence gene expression to mediate offspring sex.

64-7 WU, K*; NOWAK, J; BREUER, KS; Brown University; *Katie_Wu@brown.edu*

Scaling of the Performance of Passive-Pitching Robotic Flapping Wings in Hovering Flight

Many animals have evolved the ability to engage in flapping flight as a method of sustained hovering in aerial environments. Within this category, there exists a large range of wing geometries, flapping kinematics, and corresponding flight strategies. A key feature present in the flapping flight of some insects is wing rotation along the longitudinal axis (pitching), which controls the lift and drag forces generated on the upstroke and downstroke. Evidence suggests that prominent characteristics of this wing pitching behavior- pitch reversal during stroke transitions and maintenance of a high angle of attack during the mid-stroke - are influenced by inertial and aerodynamic forces with largely passive contributions from the wing hinge joint, which can be accurately modeled as a torsional spring. In this work, we study the relationship between aerodynamic, inertial and elastic forces in the regulation of wing pitch and the generation of forces in hovering flight with passive-pitching flapping wings. We demonstrate an experimental system consisting of an underactuated robotic model of a two degree of freedom wing with a prescribed wing stroke and an elastic wing hinge joint. We measure wing kinematics and aerodynamic forces over a range of wing geometries, hinge stiffnesses, and flapping frequencies. Our results reveal a consistent dependency of the lift coefficient on the Cauchy number (the ratio of aerodynamic pressure to elastic stiffness) over a range of parameters. The lift coefficient initially increases with Cauchy number, attains a maximum, then gradually declines, a finding which is consistent with previous results (Ishihara et al, 2009) for a system in a very different flow regime.

79-4 WU, C*; HOWLE, LE; MCGREGOR, AE; MCGREGOR, R; NOWACEK, DP; Marine Science and Conservation, Duke University, USA, Mechanical Engineering and Materials Science, Duke University, USA, School of Life Sciences, University of Glasgow, UK, High Def Aerial Surveying Ltd, UK; *chen.yi.wu@duke.edu*

Computational fluid dynamics simulations of a 10m North Atlantic right whale (Eubalaena glacialis)

Drag occurs when an object moves through a fluid due to the viscosity of the fluid. Accurate estimations of drag on marine animals are required if one wants to investigate the locomotive cost, the propulsive efficiency, and, in our case, the impacts of entanglement while the animal is carrying fishing gear. In this study, we performed computational fluid dynamics (CFD) analysis over a 10m (length of animal, LOA) static right whale model in a commercial flow solver (SolidWorks Fluid Simulation 2015) to obtain baseline measurements of drag on the animal. Swimming speeds covering known right whale speed range (0.125 m/s to 8 m/s) were tested. We found a weak dependence between drag coefficient and Reynolds number. At a swimming speed of 2 m/s, we analyzed the boundary layer thicknesses, the flow regimes, and drag components. We found the thickest boundary layer at the lateral sides of the peduncle whereas the boundary layer thickness over the outer part of the flukes was less than 1.7cm. Laminar flow occurred over the anterior ~0.6 LOA and fully turbulent flow from ~0.8 LOA to the fluke notch. On surfaces of the flukes outside of the body wake region, flow was laminar. Our most significant finding is that the drag coefficient (0.0071-0.0059) of a right whale, which is associated with the morphology the animal, for swimming speeds ranging from 0.25 m/s to 2 m/s is approximately twice that of many previous drag coefficient estimates for cetaceans.

55-3 WUITCHIK, DM*; ALMANZAR, A; BENSON, B; BRENNAN, S; CHAVEZ, D; LIESEGANG, M; REAVIS, J; SCHNIEDEWIND, M; TRUMBLE, I; DAVIES, SW; Boston University ; *wuitchik@bu.edu*

Genomic Basis of Convergent Phenotypic Responses to Thermal Extremes in a Temperate Coral

Thermal stress affects organisms on multiple levels of biological organization, from cellular stress to behavioural thermoregulation. Typically, an individual's responses to cold and heat stress at the cellular level are divergent; however, their behavioral responses may be similar at thermal extremes. *Astrangia poculata* is a temperate stony coral that lives subtidally on the East coast of the United States and experiences large temperature ranges throughout the year (3 ºC to 25 ºC). To examine how *A. poculata* responds to these thermal extremes across behavioral and molecular scales, we conducted two common garden thermal stress experiments (cold, heat) and monitored behavioral responses to food stimuli and measured genome-wide gene expression. Behaviorally, both cold and heat stress caused polyp retraction and individuals appeared to enter quiescent-like states. In contrast, gene expression profiling across the two experiments revealed functionally divergent responses to the two thermal extremes at the molecular level, relative to control conditions. We found that the molecular underpinnings behind the quiescent-like behaviors observed under both heat and cold stress were associated with distinct functional pathways, and a wide range of genes were identified as core thermal response genes within each stressor. These results illustrate how identical behavioural responses can be underscored by significantly different mechanisms and highlight how a temperate stony coral can physiologically withstand such a broad range of ambient environmental temperatures.

P2-175 WULF, G/W*; MEY, K; SETHURAMAN, A; SUSTAITA, D; California State University San Marcos; *wulf001@cougars.csusm.edu*

Population Genetics, Form, and Function of Loggerhead Shrikes in California

Population genetics studies of Loggerhead Shrikes (Laniidae: *Lanius ludovicianus*) in California have indicated considerable intraspecific genetic differentiation. Other morphological and behavioral studies have also shown geographic phenotypic variation. However, the concordance between genetic and phenotypic differentiation remains obscure. Here we explore the extent to which genetic differences among populations are correlated with phenotypic differences (beak shape and bite force) among populations of Loggerhead Shrikes throughout California. Feather samples were collected from shrikes in locations along an approximately 950 km range. Genomic DNA was then extracted and we genotyped each individual at 7 different nuclear microsatellite loci. Preliminary pairwise F_{st} values, along with MULTICULST analyses show evidence of population structure among some of these locations, suggesting a potential genetic basis to the observed phenotypic differences among some, but not all, populations. We expect that by increasing our genotyping with more microsatellite loci and sampling more individuals across California, we can perform more rigorous analyses of population structure that will shed light on the relative roles of local adaptation and plasticity in shaping differences in feeding morphology and function.

P3-185 WYETH, A.*; QUIROGA ARTIGAS, G.; SCHNITZLER, C. E.; Hope College, Whitney Laboratory for Marine Bioscience; *alexandra.wyeth@hope.edu*

A detailed head regeneration timeline in the cnidarian Hydractinia symbiolongicarpus

Tissue regeneration is widespread throughout the animal kingdom, although most regenerative animals have a limited capacity for the structures they can regenerate. The colonial cnidarian *Hydractinia*, however, has the remarkable ability to regenerate any structure throughout its lifespan, including regenerating its head structures (mouth, tentacles, neurons, stinging cells) within about 72 hours. Migratory stem cells, known as interstitial cells ('i-cells'), typically reside in the body column of *Hydractinia* feeding polyps. Head regeneration is accomplished via the proliferation of these i-cells forming a blastema structure that gives rise to all head structures. In this study, we established a detailed timeline of head regeneration in *Hydractinia symbiolongicarpus*. To better understand this process at a cellular level, we performed a series of experiments including live imaging, immunohistochemistry, and cell proliferation assays over a time course of regeneration. Most polyps completely regenerated their head within ten days, with first tentacle buds occurring between 48 and 72 hours post dissection. Immunofluorescence staining showed wound closure within four hours, while nervous system regeneration and the appearance of stinging cells around the newly formed mouth and in the budding tentacles occurred between 48 and 72 hours after dissection. EdU staining and pulse-chase experiments revealed the essential contributions made by the pool of proliferating i-cells to all regenerated head structures. Our results confirm initial observations made in a sister species of *Hydractinia* and provide a more detailed understanding of the head regeneration process in *Hydractinia* that will be used as a basis for future studies of this highly regenerative species.

P1-72 WYND, BM*; MARTINEZ, RN; Virginia Tech, Blacksburg, USA, Museo de Ciencias Naturales, San Juan, Argentina; *bmwynd@vt.edu*

A review of vertebrate beak morphologies in the Late Triassic; a framework to phylogenetically place an enigmatic beak from the Ischigualasto Formation, San Juan, Argentina

The fossil record rarely preserves direct evidence of ecology (e.g., gut contents), but it does preserve many cases of convergent morphology, which suggests similar ecologies. A beak, which is an edentulous dietary modification present in vertebrates and invertebrates convergently evolves repeatedly throughout the Phanerozoic. Here, we focus on the earliest evolution of beaks in the reptile fossil record during the Triassic Period (252 - 201.5 million years ago). We divide Triassic beaks into three morphotypes: 1) triangular, beak tapers to a point anteriorly, thin lateral walls, sharp occlusally; 2) square, a beak squared off anteriorly, thin lateral walls; 3) predentary, triangular beak, rounded lateral walls, concave midline shelf. With this subdivision, we analyze the phylogenetic distribution of Triassic beaks and a unique fossil beak (PVSJ 427) from the Ischigualasto Formation, San Juan, Argentina. PVSJ 427 is a small hematite-encased fossil that is triangular with a concave midline shelf, rounded lateral walls, and an anterior point. No bone is currently recognizable on the surface of PVSJ 427, indicating that it could be a natural cast of a beak or it could be a rhamphotheca encased in hematite. The rounded walls and midline shelf most closely matches the predentary morphotype, which is restricted to ornithischian dinosaurs, though this specimen is ~3 times larger than the earliest known Jurassic ornithischian beak. Regardless of phylogenetic position, PVSJ 427 reflects the earliest-known evolution of the predentary-like morphotype in vertebrates and indicates that this animal was likely exploring similar feeding ecologies to later-known ornithischian dinosaurs.

44-4 WYNEKEN, J*; LOLAVAR, A; LASALA, J; Florida Atlantic Univ.; *jwyneken@fau.edu*

Lethal Phenotypes and Cryptic Consequences from Extreme Developmental Conditions in Sea Turtles

Reptile species that lay their eggs and leave them unattended to incubate depend upon nest environments to be benign and promote successful hatchling production. Successful embryonic development requires a relatively narrow range of thermal and hydric conditions. Concerns about the effects of changing climates on incubation environments tend to focus upon on thermal maxima and thermal effects on embryonic sex. Here we describe developmental outcomes in sea turtles that include phenotypes that are associated with hyperthermia and desiccation. We find an increase in frequency of morphological anomalies in hatchlings that incubated for all or part of development at or above previously presumed lethal temperature. Scute abnormalities are the most common anomaly. However, we also identified a variety of craniofacial anomalies and flipper malformations. Several anomalies that were previously rare included extreme hyperlordosis and cranial neural tube defects were found in nests with high incubation temperatures. Turtles that incubated under extremely warm dry conditions hatched from nests with poor overall success. We documented several cryptic phenotypic effects that can result in delayed mortality or reduced likelihood of survival including variation in growth rates and gastrointestinal anomalies. Mortality was often associated with yolk sac inflammation, short or incomplete intestines, and rectal stenosis. Together these observations suggest that hyperthermia and desiccation during the development of these ectothermic species may contribute additive negative impacts to the populations that previously have not been appreciated.

P2-80 XIANG, A*; GAGLIO, A; PELLICANO, A; GARDYN, N; SHALOV, J; LYNCH, KS; Hofstra University; *angellx0607@gmail.com*

Comparison of candidate genes in hypothalamic brain regions in blackbirds with stark divergence in maternal care strategies

The external conditions that contributed to the evolution of avian obligate brood parasitism have been well-studied whereas the intrinsic mechanisms are less well understood. Our lab previously identified differentially expressed transcripts specific to the preoptic area (POA) in brood parasitic and a closely related non-parasitic species. We selected six maternal care-related candidate genes and compared their expression in additional hypothalamic regions in parasitic bronzed cowbirds (Molothrus aeneus) and non-parasitic red-winged blackbirds (Agelaius phoeniceus). We compared genes with neuromodulatory and structural functions including mesotocin (avian homolog of oxytocin), arginine vasotocin (homolog of vasopressin), galanin, prostaglandin synthase, stathmin and mesencephalic astrocyte derived neurotrophic factor (MANF). We compared expression patterns of these genes in a pooled sample that contained tissue punches from the lateral hypothalamus, tuberal nucleus, ventral medial hypothalamus, and posterior medial hypothalamus. Results reveal that differential expression of these genes between parasitic and non-parasitic blackbirds is not specific to the POA. We found significant differences between parasite and non-parasite species in all transcripts within these additional hypothalamic regions. These results suggest that the POA is likely not the only brain region that was targeted by evolution to produce this novel behavioral phenotype as additional hypothalamic regions exhibit similar gene expression differences between parasitic and non-parasitic species. Additional studies will examine brain regions within other social behavior-related regions to identify the full suite of neural architecture that may underlie the brood parasitic strategy.

127-4 XU, NW*; DABIRI, JO; Stanford University; *nicolexu@stanford.edu*

Stimulation of latent enhanced propulsion in free-swimming jellyfish

External control of freely swimming jellyfish can facilitate testing of hypotheses regarding the evolution of efficient locomotion. It also enables an approach to soft robotics that simultaneously addresses longstanding challenges related to actuation, control, and power requirements in applications such as ocean monitoring. Here, we present a biohybrid robot that uses implantable microelectronics to induce swimming in native *Aurelia aurita*. Measurements show that propulsion can be significantly enhanced by driving the body contraction frequency above natural behavior, with an observed peak enhancement up to three times faster than natural swimming. However, biological constraints at higher frequencies can decrease swimming performance. The existence of latent enhanced performance has implications for the evolution and ecology of swimming animals, and it can potentially be leveraged to expand the performance envelope of biohybrid robots relative to native animals.

34-3 XU, RU*; ZHANG, X; LIU, HAO; Graduate School of Engineering, Chiba University, Chiba 263-8522, Japan, Shanghai Jiao Tong University and Chiba University International Cooperative Research Centre (SJTU-CU ICRC), Shanghai, People's Republic of China; *chibaxuru@gmail.com*

Dynamic Flight Stability in Hovering Bumblebee Can be Enhanced by Passive Feathering Mechanism: A Computational Study

Insects with flapping wings require agility towards ambient disturbances to maintain airborne and stabilization. Insects adopt subtle changes in wing kinematics to overcome the perturbations, and passive feathering, which indicates passive response of feathering angle toward aerodynamic and inertia torque , is highly possible to exist in insect. To investigate the stability of insect with passive feathering mechanism, bumblebee model is used with 6 degrees of freedom in rigid body assumption, and 1 degree of freedom for each separate wing in wing feathering direction. One directional perturbations are applied to body. Body attitude angles are compared in passive feathering system and active feathering (wing feathering angle remains the same as experimental values under perturbation) in several strokes. It shows that under symmetric perturbation, stability of passive system and active system behave similarly while under asymmetric perturbations, roll stability of passive system is enhanced through the different passive reaction of two wing hinges toward perturbation. Passive feathering mechanism reduces wing hinge complexity, and makes it a promising for Micro Air Vehicle design and stability.

86-4 XU, LC*; WANG, VR; NUNES, C; SAITO, A; KOYAMA, T; SUZUKI, Y; Wellesley College, Gulbenkian Institute, Gulbenkian Institute; *lxu3@wellesley.edu*

Developmental mechanisms of life history trade-offs: varying JH titers lead to distinct PG activity in Manduca and Drosophila

Life history trade-offs lead to various strategies that maximize fitness, but the developmental mechanisms underlying these alternative strategies continue to be poorly understood. In insects, trade-offs exist between size and developmental time. The fruit fly, *Drosophila melanogaster*, for instance will sacrifice a larger size for a faster life cycle. Contrastingly, the tobacco hornworm, *Manduca sexta*, takes a longer time to reach its final adult stage in order to maximize their adult body size. Recent studies in *Drosophila* have suggested that the prothoracic gland plays a key role in determining the timing of metamorphosis. In this study, we compared the growth and gene expression of prothoracic glands in *Drosophila* and *Manduca* to begin to understand how the life history trade-offs might be diverge. Our findings suggest that differences in juvenile hormone production determines the nutrient-dependency of prothoracic gland activity and that the prothoracic glands is the focal gland that mediates differences in life history strategies.

64-1 XUAN, Q*; OTHAYOTH, R; LI, C; Johns Hopkins University; *qxuan1@jhu.edu*

In silico experiments reveal the importance of randomness of motions in cockroach's winged self-righting

Terrestrial animals must self-right when overturned to survive. The discoid cockroach *Blaberus discoidalis* can dynamically self-right by opening its wings to push against the ground while flailing its legs to induce body vibration. Interestingly, although wing and leg motions are oscillatory, they both have a substantial degree of randomness. Here, we test the hypothesis that randomness in these motions is useful for self-righting. We developed a multi-body dynamics simulation of a cockroach-inspired self-righting robot, with simplified body morphology and controlled, modifiable motions. The robot repeatedly opened and closed its wings and oscillated an appendage mimicking flailing legs to induce body vibration. We first validated the simulation against robot experiments and then used it to perform experiments in silico to study the effect of randomness. With strictly periotic wing and appendage oscillations (no randomness), the robot self-righted at a modest probability (62 ± 11 %) within 5.0 ± 0.8 seconds. After randomness was introduced, however, the robot almost always self-righted (99 ± 4 %) within 3.6 ± 0.7 seconds. By systematic parameter variation, we discovered that an appropriate phase offset between wing and appendage oscillations when the body pitched up was critical to self-righting. Strictly periotic wing and appendage oscillations limited the coupled oscillator system to visit only a small number of phase offsets, often causing it to be trapped near failure limit cycles. Added randomness in wing and appendage oscillations allowed the system to explore a diversity of phase offsets, increasing its probability to escape failure limit cycles and self-right. Our study reveals the importance of coordination between body parts and the usefulness of randomness of motions in self-righting.

139-2 YAEGER, J. M.*; AMTHOR, A. E.; LUNA, M.; NOEL, A. C.; NADLER, J. H.; Georgia Tech Research Institute; *jonathan.yaeger@gtri.gatech.edu*

Passive Fluid Transport Properties and Biomimetic Potential of Aerial Orchid Roots

Epiphytic orchids absorb water and nutrients passively via specialized aerial roots, which contain a spongy outer layer of dead cells known as the velamen radicum. When exposed to precipitation, this layer saturates within seconds and can retain water for hours, acting as a temporary reservoir for the orchid. Until now, no attempt has been made to replicate the aerial orchid root structure for passive fluid transport. Here, we investigate the physical structure of roots using optical microscopy and SEM. We also measure the relative humidity uptake of roots in a sealed container to determine whether roots can condense water vapor. In addition, we characterize the fluid distribution behaviors of root sections and detached velamina using fluorescent video imaging. Initial results indicate that fluids spread rapidly across the surface area of the velamen with a consistent time dependence and without significant directional bias. The relative humidity tests show that orchid roots do not condense water vapor, suggesting an entirely passive fluid absorption mechanism. These results demonstrate that the aerial orchid root structure shows potential for fluid transport applications, such as fluid redistribution in diapers or water harvesting in arid environments.

116-2 YAMAMOTO, KY*; VANGLA, P; FROST, JD; Georgia Institute of Technology; *kyamamoto8@gatech.edu*

2D and 3D laboratory studies to understand tunneling behavior of Pogonomyrmex occidentalis in different soil conditions

Bio-inspired geotechnics is an emerging field with potential to find insights and solutions to geotechnical engineering problems. For instance, ants perform tunneling using highly optimized techniques to minimize the amount of energy expended to build a nest and excavate stable nest structures by adapting to environmental conditions. By sensing the environmental conditions at the tunnel face, ants utilize a feedback loop system to optimize the excavation process. Therefore, studying the excavation behavior of ants in different soil conditions can provide insights to improve the design and construction of tunnels and potentially develop smart excavation technologies. This study explores the excavation behavior of ants in monolayer and distinct layers of soil with different particle sizes and densities by analyzing the nest geometry and digging rates. For this purpose, a series of 2D and 3D laboratory experiments were carried out. Timelapse photography images were recorded as ants excavated in 2D-effective rectangular acrylic chambers containing the soil samples. Image analysis techniques were then used to capture the geometry, digging rates, and cumulative volume of soil excavated. In the case of 3D experiments, the geometry of the nest was analyzed from paraffin wax castings, and the total volume of excavation was estimated using the volume of wax placed in the nest. Based on the results, changes in particle size and density do not influence average tunnel diameter, however from the digging rates and volume of soil excavated, there is a preference for soils with lower densities and smaller particle size.

114-1 YANG, Y*; RICHARDS-ZAWACKI, CL; Univ. of Pittsburgh; *yusan.yang8@gmail.com*

Can male contest limit assortative female preference in a polymorphic poison frog?

Assortative mate preferences (i.e. preferring mates of a similar phenotype to one's self) are hypothesized to limit gene flow and accelerate reproductive isolation among young lineages. However, male-male competition can restrict, and may, in many mating systems, override female preference. The strawberry poison frog (*Oophaga pumilio*) is one notable example of a species with dramatic phenotypic divergence that may be involved in reproductive isolation. Female mate preferences have co-diverged with color in most populations tested, but the extent to which such assortative preferences can effectively reduce gene flow among color morphs when accompanied with male-male competition is not clear. Here, we experimentally evaluated the relative importance of color-mediated female preference and male-male competition, testing the hypothesis that male territorial contest results limit the female from choosing her preferred color. We first set up a dyadic contest between two different colored males; upon establishing a stable hierarchy (i.e. a clear winner and loser), we introduced a female with a preference for the loser male's color. This breeding trio was kept together until they produced tadpoles, which we then genotyped to reveal paternity as direct evidence of reproductive success. Results showed that females were more likely to (but did not exclusively) mate with the winner male that had the less attractive color. Our results highlight the importance of male-male competition, a less-studied part of sexual selection, in shaping the process of phenotypic divergence and speciation.

7-5 YANG, D*; ROCHO-LEVINE, J; MOORE, M; SHORTER, K; JOHNSON, M; University of Michigan, Dolphin Quest, Oahu, Woods Hole Oceanographic Institution, University of St, Andrews; *yangyayu@umich.edu*

In-Vivo Measurements of Bottlenose Dolphin Skin Under Pressure Loading

Bio-logging tags that enable behavioral studies of marine mammals are often secured using suction cups to minimize impact to the animals. However, suction cup performance is dependent on the dynamics of the attachment surface. Marine mammal skin is made up of tissue layers that possess viscoelastic properties and exhibit a nonlinear stress-strain relationship during loading, but in-vivo measurements of the tissue at the attachment sites are lacking. Further, the highly integrated tissue layers that make up the skin are not distributed uniformly, resulting in a variable viscoelastic composite. The goal of this research is to characterize the response of the composite tissue under vacuum loading. In our preliminary work, a static suction cup (SSCup), a half-dome device equipped with a linear variable differential transformer, was used to measure the peak skin displacements under three types of loading (static step vacuum loading, repetitive loading, and creep/relaxation) at three different sites (Site 1: anterior to the blowhole; Site 2: above the pectoral fin; Site 3: below the dorsal fin) on six bottlenose dolphins. The results indicate Site 3 is stiffer than Sites 1 or 2 and shows little hysteresis, while Sites 1 and 2 have comparable force vs displacement curves. While promising this system only measures the maximum deformation of the skin. To enable full field deformation and strain measurements, this study presents a portable 3D-printed device that uses digital image correlation to make full field deformation and strain measurements of skin. These results will lead to a better understanding of the tissue and facilitate improved suction cup design.

72-1 YEGIAN, AK; Harvard University; *ayegian@fas.harvard.edu*

Bigger Bipeds, Shorter Arms: Inter-Limb Scaling in Hominins and Theropod Dinosaurs

Humans have relatively short arms compared to their hominin ancestors. Traditionally, the evolution of shorter arms relative to the legs has been interpreted as a gradual behavioral transition from generalist locomotion (including climbing) to near-obligate bipedalism. This interpretation is supported by R.M. Alexander's Dynamic Similarity hypothesis, which states that two animals of different sizes have similar gaits if they travel at the same dimensionless speed AND are isometrically scaled. However, I challenge the notion that inter-limb isometry is a condition for similarity in bipeds. Instead, I argue that similarity is conditioned on having the same mass-specific joint stiffness at the shoulder during arm swing, and that longer legs require relatively shorter arms for similarity. I derived a simple quantitative arm swing similarity model using walking data from humans, and show that the model reasonably predicts fossil hominin arm lengths for all but the earliest species. I conclude that a behavioral transition is not necessary to explain the evolution of limb proportions in hominins, and that the modern human walking gait may have evolved much earlier in the hominin lineage than thought. When the same model is applied to non-avian theropod dinosaur limbs, they too fall along an arm swing similarity scaling relationship. The similarity model outperforms isometric models in both taxa, and has the strength of being derived from first principles. Furthermore, the swing similarity model is generalized and can be applied to leg swing in the future. Surprisingly, insights into why human arms are relatively short may have led to an answer to the age-old question of why *T. rex* arms were so short: bigger bipeds require relatively shorter arms for similar arm swing mechanics.

107-5 YEN, J.*; LI, W.; Georgia Institute of Technology; *jeannette.yen@biosci.gatech.edu*
Teaching Biologically Inspired Design
At Georgia Tech, we teach an interdisciplinary bio-inspired design class with teams made up of biology, mechanical engineering, materials science, biomedical engineering, and architectural/industrial designers. Bio-inspired design provides a framework for teaching the fundamentals of interdisciplinary work, including how to find, read and understand biology papers, how to decompose problems, and how to ensure that a biological understanding will translate to solving their technical challenge. Ultimately in the course, students use these biological "wonders of the world" to create better and more sustainable engineered designs. The resulting student innovations are always astonishing; but more importantly, the students learn how to communicate and work across disciplines. This bio-inspired design framework provides one way for teaching the next generation how to deal with today's complex, multi-disciplinary design challenges.

63-1 YOPAK, KE*; MCMEANS, BC; MULL, C; FEINDEL, KW; KOVACS, KM; LYDERSEN, C; FISK, AT; COLLIN, SP; Univ of North Carolina Wilmington, US, Univ of Toronto Mississauga, Canada, Simon Fraser University, Canada, Univ of Western Australia, Australia, Norwegian Polar Institute, Norway, Univ of Windsor, Canada; *yopakk@uncw.edu*
A Small Brain and a Big Nose: Comparative Brain Morphology of the Greenland and Pacific Sleeper Sharks
Variability in the size and complexity of the brain and its major regions in cartilaginous fishes is often associated with habitat and/or specific behavior patterns, providing a link between brain form and specialized function. The Greenland (*Somniosus microcephalus*) and Pacific sleeper (*S. pacificus*) sharks are two of only a few shark species known to occur in the Arctic and are among the longest living vertebrates ever described, though many aspects of their behavior, life history, and basic biology remain poorly understood. Among the most distinctive characteristic of *Somniosus spp.* is the presence of ocular lesions. Despite a presumed visual impairment caused by this parasite, coupled with the fact that locomotory muscle power is often depressed at cold temperatures, these sharks remain capable of capturing active prey, including pinnipeds. Therefore, the central nervous system of these two unique shark species was examined as a way of predicting the relative importance of different sensory modalities in predatory behavior. Using magnetic resonance imaging, we assessed relative brain size and brain organization of *S. microcephalus* and *S. pacificus* in the context of a broad range of other shark species (n=117). Notably, the region of the brain responsible for motor control (cerebellum) is small and lacking in foliation. Further, the development of visual brain regions are relatively reduced, while the olfactory brain regions are among the largest of any shark species described to date, suggestive of an olfactory-mediated prey tracking behavior in a slow moving predator.

P2-197 YOUNG, MG*; MCMAHON, TW; ANGELINI, DR; Colby College; *mgyoun21@colby.edu*
Bombus Microbiome Diversity and Pathogen Prevelence in the State of Maine
Bumblebees are critical, native pollinators, contributing to both local ecosystems and agriculture throughout North America. Similar to the honeybee, many *Bombus* species have faced decline over recent years due to multifaceted causes that work in conjunction to overwhelm the natural defenses of bees (Goulson et al. 2008; 2015). Currently, Maine's endemic populations are threatened by the use of agrochemicals, climate change, and various diseases and parasites. Through ecological genomic research, we have investigated both the range and diversity of the Maine bumblebee species and looked for correlations between microbiome composition and anthropogenic and environmental factors. This has been accomplished through 16s and 18s sequencing of field samples collected across the diverse biomes of the state during the summers of 2017 and 2018. Analysis of species distribution suggests that many of the coastal islands act as refuges for threatened bees due to their geographic isolation from the mainland. With our data, we have assessed the prevalence of known pathogens, such as *Crithidia*, *Nosema*, and *Apicystis*. Previous research indicates that bumblebees forage within a maximum range of 5 km (Goulson 2010; Stubbs & Drummond 2001; Dibble et al. 2017). We tested the hypothesis that islands outside of this daily foraging range are geographically isolated from the spread of both pathogenic and benign microbes by comparing island and mainland samples with differential abundance analysis of observed OTUs and the use of various diversity metrics. Taking into account both the microbiotic and metadata profile collected on each sample, we used statistical analysis to further examine for predictors of microbiome health and other correlations within our data.

P2-189 YOUNG, CM*; JEBB, KE; MORAN, CJ; GERRY, SP; Fairfield University, The Citadel; *carolineyoung072@gmail.com*
Effects of Muscle Acclimation to a Thermal Regime
Investigating the differences in muscle physiology between lab acclimated fish and those taken from the wild can help us understand the impacts of thermally acclimated fish in a laboratory. Additionally, these comparisons allow us to evaluate the inferences made on fish in the wild by laboratory studies. To address these topics we asked the question, does muscle physiology in wild cunner (*Tautogolabrus adspersus*) differ from cunner in the lab? We hypothesized that 20°C acclimated cunner would produce greater power output and muscle kinetics compared to 20°C natural cunner. Lab acclimated cunner (n=5) were collected from Long Island Sound and held for 4 weeks at 20°C. Similarly, the natural cunner were caught when ocean water reached 20°C. To address our hypothesis, we examined the effects on power output and muscle kinetics with cunner tested at 20, 10, and 5°C. The 20°C acclimated cunner had a greater twitch force per PCSA, as well as power output at 5, 10, and 20°C. Additionally, throughout each testing temperature, power output for lab acclimated cunner was greater at every frequency. However, the time to maximum twitch contraction and relaxation were relatively similar between acclimated and natural cunner at every testing temperature. The difference in power output and force PCSA could indicate that muscle in thermally acclimated fish underwent a change to produce greater results. Furthermore, this data could suggest that lab acclimated fish are not accurate comparisons to those in the wild.

84-6 YOUNGBLOOD, JP*; VANDENBROOKS, JM; ANGILLETTA , MJ; Arizona State University, Midwestern University; *jpyoungb@asu.edu*

Dynamics of heat tolerance during development of locusts

Predicting how organisms will respond to climate change requires a detailed understanding of how all life-stages respond to heat stress. Indeed, an animal's heat tolerance changes during development, but the physiological mechanisms underlying these changes remain unknown. One proposed mechanism, known as oxygen limited thermal tolerance, occurs when metabolic demand during warming outstrips the energy supplied by aerobic respiration. Although this hypothesis has minimal support from studies of adult insects, early life-stages with less developed respiratory systems may be more susceptible to oxygen limitation. For example, as locusts develop, their capacity to deliver oxygen increases with each successive instar. Further, oxygen may become increasingly limited as locusts approach their next molt since the tracheal system does not grow during an instar. Here, we evaluated whether these ontogenetic shifts in oxygen delivery correspond with changes in heat tolerance in the South American locust (*Schistocerca cancellata*) and the American locust (*Schistocerca americana*). We measured changes in heat tolerance both within and among instars, as well as the effect of hypoxia on heat tolerance in each of these stages. Hypoxia decreased the survival of 1st-instar locusts at high temperatures, but did not do so for survival of any other instars. Within the 6th and final instar, heat tolerance decreased as animals progressed through the instar, but there was no effect of hypoxia on heat tolerance at any time during the 6th instar. These results suggest that oxygen limitation explains some of the ontogenetic variation in heat tolerance in locusts, but other variables can play a more important role depending on the life-stage.

P3-87 ZAHOR, DL*; GLYNN, KJ; CHIPARUS, SL; CORNELIUS, JM; Eastern Michigan University; *dzahor@emich.edu*

Species, age and foraging-niche variation in blood lead levels in urban and rural songbirds

Anthropogenic metal pollutants emitted into the environment have the potential to harm organisms residing in the polluted ecosystem. Urban birds spend much of their time in human-dominated landscapes and could serve as bioindicators of metal pollution as well as possibly reflect human exposure. Lead is a persistent heavy metal in the environment that can act as a neurotoxin when it reaches high levels within an organism. Diets vary widely in songbirds and species that forage on soil-dwelling organisms may be more prone to lead exposure. Similarly, if young are fed preferred items there may be differences in exposure between adults and juveniles. Finally, species that associate strongly with human structures may differ in exposure to lead. In this preliminary study, we describe blood lead levels in four species of urban songbirds: two omnivores that forage frequently for soil-dwelling organisms and two granivores, including an invasive and native species of each. We will discuss the influence of diet, age and ecological niche on lead levels in these urban songbirds. Understanding factors that increase a species sensitivity to pollution can better guide conservation efforts and raise public awareness surrounding pollution risks to wildlife.

P3-36 ZALASKUS, KA; BARTOL, SM*; BARTOL, IK; Old Dominion University, Norfolk, VA, Virginia Wesleyan University, Virginia Beach, VA; *kjaco001@odu.edu*

Swimming Kinematics of Loggerhead Sea Turtles during Early Ontogeny

Sea turtles embark on extensive transoceanic migrations during early ontogeny, often moving into and out of prevailing currents in search of target food sources. Although efficient swimming is essential to a turtle's survival, surprisingly little is known about sea turtle swimming capabilities during the critical first year of life. In this study, we examined swimming kinematics of loggerhead sea turtles *Caretta caretta* through their first year of life, with an emphasis on documenting sustained swimming speed capacity, stability, and flipper motions. Each of four post-hatchling loggerhead sea turtles was placed in a 1000-gallon water tunnel at 3, 4, 5, and 6 months of age and subjected to a stepwise increase in current speed while three high-speed digital video cameras simultaneously recorded their swimming motions. Critical swimming speed ranged from 13 to 20 cm/s for turtles 3-6 months of age. Turtles achieved higher swimming speeds by increasing the frequency, vertical arc angle, and horizontal amplitude of their foreflipper strokes. Body pitch angle decreased with increased swimming speed, but body roll and yaw did not change significantly with increased swimming speed. Recoil motions decreased with ontogeny, suggesting that sea turtles improve their swimming proficiency with age and/or with experience swimming in the water tunnel. No abrupt kinematic shifts indicative of gait transitions were observed across the speed range tested. Our results suggest that young turtles are capable of making gradual adjustments to their flipper motions and body positioning to achieve higher swimming speeds.

P3-174 ZAMACONA GONZALEZ, R.*; WILCOXEN, T.E.; ZIMMERMAN, L.M.; Millikin University; *rzamaconagonzalez@millikin.edu*

Isotype switching and spleen development in Rana catesbeiana

Compared to immunity in adult frogs, little is known about immunity in tadpoles. It has been demonstrated that *Rana catesbeiana* tadpoles can isotype switch from IgM to IgY three weeks after exposure to an antigen. However, the exact timing of this has not been determined. The time period of isotype switching in *Rana catesbeiana* was studied in 90 tadpoles, in addition to the development of their spleens. We divided the tadpoles into two different groups, the control group and the immunized group. Control tadpoles received 10 µL of a 50/50 of phosphate buffer solution (PBS) and alum. Immunized tadpoles received 10 µL of 50/50 solution of 10 µg/µL of keyhole limpet hemocyanin in PBS and alum. Two tadpoles from the control group and four from the immunize group were selected randomly to be sampled every three days. We discovered that the immunized group had a larger spleen than the control group. The antibody levels to KLH will be measured using an ELISA. These results help us in determining the period of time it takes the tadpoles take to isotype switch from IgM to IgY. This information could be used in future research to investigate factors such as stress levels, change in temperature, and change in resource availability could affect the length of time that *Rana catesbeiana* takes to respond to novel antigens.

P2-78 ZAMORE, SA*; SOCHA, JJ; Virginia Tech; *zamore@vt.edu*
Development of a virtual reality arena to study vision in flying snakes
Virtual reality is widely-used tool for exploring perception and decision-making in animals such as cockroaches, mice, fruit flies, bees, moths, and hummingbirds. By placing animals in a closed-loop environment, researchers can manipulate feedback (by temporally offsetting the response from a behavior, for example) such that requisites for locomotion or perception are revealed. Here, we demonstrate a new virtual reality environment, which we are developing to explore how flying snakes (*Chrysopelea*) visually perceive the environment during locomotion. The virtual arena consists of a 3-ft cube lined with PVC fabric, upon which images are back-projected (Epson VS350 XGA projectors). The system tracks the snake's head and body position using infrared (IR) reflective markers, commercial gesture sensors (Leap Motion), and custom computer vision scripts. The virtual world imagery, created using Unity software, is updated continuously using the tracked the head positions. To observe the snake's undulatory movement without translation, we designed air table that provides a zero friction surface. This new closed-loop virtual reality system will enable us to gain insight into how snakes use vision to move through their environment, and to react to specific visual features (such as looming and retreating objects). Supported by NSF 1351322 and 1402558.

P1-199 ZAPFE, KL*; FRéDéRICH, B; SANTINI, F; FEDERMAN, S; FIELD, D; DORNBURG, A; Clemson University, University of Liège, Associazione Italiana per lo studio della Biodiversita, Yale University, University of Bath, North Carolina Museum of Natural Sciences; *kzapfe@clemson.edu*
Collapsing Hotspots, Extinction, and Recovery: The Evolutionary History of Herbivorous Reef Fishes
Herbivorous reef fishes have evolved to occupy a central role in controlling both the distribution of algae and the flow of energy in coral reef food webs. Today, these fauna and the ecosystems they maintain have become increasingly threatened by anthropogenic stressors. Developing an understanding of how the diversification dynamics of these lineages responded to historic climatic shifts provides critical insight into the expectations of herbivorous fish diversity under current models of climatic change. We combined molecular, paleontological, and morphological data to assess the diversification dynamics of rabbitfishes (Siganidae) and surgeonfishes (Acanthuridae), two major clades of herbivorous fishes that have been of central ecological importance over the past 50 million years. By combining landmark-based geometric morphometric data of 396 extant and fossil species images with a time-calibrated phylogeny, we found diversification of both clades reflected the expectations of an extinction recovery model following the collapse of the West Tethys Sea. The two groups however exhibit differing tempos of speciation as well as extant morphospace occupancies relative to Eocene species. Our results indicate the viability of multiple evolutionary pathways leading to lineage persistence in the wake of environmental change. However, given modern-day trends in habitat degradation, they also forewarn of future patterns of diversity not dissimilar to those of the post Tethyian collapse favoring fewer, more generalized herbivores on reefs unlike those of the present.

38-7 ZELDITCH, ML*; LI, J; SWIDERSKI, DL; Univ. of Michigan, Ann Arbor, Univ. of Colorado, Boulder; *zelditch@umich.edu*
Stasis of Functionally Versatile Specialists
Long-term stasis seems paradoxical, but several ecological hypotheses could explain persistence of a morphology for millions of years despite dramatic environmental change. Testing those hypotheses, however, can be complicated owing to processes that either mimic or mask long-term stasis. What might seem like long-term stasis could instead be due to a rapid, recent adaptive radiation; conversely, a few highly divergent forms might mask persistence of an ancestral morphology in otherwise static lineages. We examine diversification and divergence of jaw shape in three tree squirrel lineages, one considered a living fossil (Sciurini), which underwent a recent Neotropical radiation. Another (Callosciurinae), was tentatively interpreted as a living fossil but it contains several distinctive morphologies including some extreme specialized forms. The third (Pteromyini) has never been viewed as static. We find that Sciurini is half as disparate as Callosciurinae and Pteromyini. Apart from two ecologically specialized morphs, Sciurini occupies a single, stable adaptive peak. Despite its greater disparity, Callosciurinae is nearly identical to Sciurini in its stationary variance; its disparity is elevated by a larger number of adaptive peaks, many unique to a single species, and more extreme forms. In both lineages, the static morphology is specialized but is functionally versatile; these squirrels can eat the hardest nuts of the tropical rainforest although most have broad diets, also eating soft fruits, insects and small seeds. In contrast, Pteromyini is not static; in this lineage, disparity accumulates over time, at a far lower rate in a clade of specialized folivores. Our analysis supports a variant of classic hypothesis: static lineages comprise functionally versatile specialists within a broad adaptive zone because those specialists behave as ecological generalists much of the time.

S10-11 ZERA, Anthony/J; University of Nebraska; *azera1@unl.edu*
Time has come today. The importance of hormonal circadian rhythms underlying daily-rhythmic life history adaptation
Seasonal changes in the hormonal regulation of life history traits are recognized as an important aspect of life history adaptation and have attracted considerable attention. Yet, corresponding daily cycles in hormones and life histories have barely been investigated. This topic will be reviewed with particular focus on the dramatic morph-specific daily cycle in the blood titer of juvenile hormone (JH) in morphs of the cricket *Gryllus firmus* that differ in life history. Recent transcriptome profiling indicates that the morph-specific JH circadian rhythm is associated with extensive morph-specific cycles of gene expression. Failure to investigate daily variation in endocrine and molecular traits not only results in the failure to recognize an important aspect of adaptation, but also can lead to serious errors in interpreting the adaptive basis of observed variation.

86-8 ZHANG, LL; SEAVER, EC*; University of Florida; *seaver@whitney.ufl.edu*

Heads or Tails: Transcriptomic Insights into Annelid Regeneration

Whole body regeneration is widespread in the animal kingdom, although surprisingly little is known about diversity in the genetic basis of regeneration ability in a comparative context. The diverse regeneration abilities and straightforward body plan segmentation in annelids offer a unique opportunity for comparative regeneration studies. For example, the segmented worm *Capitella* teleta is capable of regenerating posterior segments but incapable of anterior structures. To identify molecular signatures of regeneration, we employed RNA sequencing to examine gene transcription across multiple stages of regeneration after amputation, and between anterior and posterior regeneration, in *C. teleta*. Our study suggests two global biological processes during regeneration, an early wound healing and a subsequent developmental patterning process. We identified 685 differentially expressed genes during posterior regeneration, including genes involved in stress response, extracelluar matrix remodeling, cell migration behavior, signaling, neurogenesis and myogenesis. We observed a number of putative early prepatterning genes that have dynamic expression patterns during regeneration. Many axial patterning genes involved in Wnt and TGF-beta/BMP signaling were significantly differentially regulated during regeneration. Several genes encoding homeobox domain proteins were also significantly regulated. Comparison analysis between anterior and posterior regeneration pinpoint a few differential expressed genes related to cell adhesion and development. The results point to previously undescribed mechanisms for organizing regeneration in annelids and will be a valuable resource for further research in regeneration biology.

P1-177 ZHANG, X*; RONALD, KL; HURLEY, LM; Indiana University, Bloomington; *xinzzhan@iu.edu*

Multimodal Female Stimuli Influence Vocal and Nonvocal Behaviors of Male House Mice (Mus musculus)

House mice use multimodal signals (e.g., auditory and olfactory) intersexual communication. However, more studies have been done on how females respond to signals from males than how males respond to signals from females. This is important because males and females can both send and receive signals during communication. Moreover, most studies tend to study nonvocal and vocal response behaviors separately instead of looking into the relationships between them; nevertheless, this relationship may give us new insights about the functions of multimodal signals. We presented female ultrasonic vocalizations (USVs), squeaks, and urine as unimodal signals and USVs+urine and squeaks+urine as multimodal signals to test male behavioral responses. We used the numbers of ultrasonic vocalizations as vocal behaviors and the duration of investigation, digging and rearing as nonvocal behaviors. We studied the correlations between each nonvocal and vocal behavior. We predicted that the correlations between male behaviors would only exist under multimodal conditions because increased information about females might cause males to produce vocal and nonvocal behaviors. .Our results supported our predictions, in that behavioral correlations only occurred during multimodal conditions. Specifically, the correlation between male investigation and USVs existed under female squeaks+urine condition and the correlation between male digging and USVs existed under female USVs+urine condition. Our results suggested that multimodal signals are more salient than unimodal signals. At the same time, correlations may have emerged because multimodal signals elicit the highest male response rate, creating a range in which individual variation can be observed.

56-5 ZHANG, Y*; HILL, G.E; GE, Z; PARK, N; TAYLOR, H; ANDREASEN, V; KAVAZIS, A.N; BONNEAUD , C; HOOD, W.R; University of Memphis, Auburn University, University of Exeter; *charlesskidd@gmail.com*

Effects of Mycoplasma gallisepticum on mitochondrial function and oxidative stress in house finch

As a major physiological system centrally involved in cellular renewal and repair, immune function is an essential component of body maintenance and survival. Immune defenses can be energetically expensive. Hence, the activities of metabolic active organs, such as liver, can be expected to be elevated as a result of immune defense activation. On the other hand, some pathogens can be immunosuppressive which would decrease immune response eventually leads to low levels of metabolic capacities in organs. Mycoplasma gallisepticum (Mg) is a bacterium that is a well-known pathogen of domestic chickens, turkeys and songbirds. In house finch (Haemorhous mexicanus), in addition to causing a respiratory infection, it would also infect the conjunctiva of the eye causing conspicuous swelling. In order to study the activities of immune defense system, we measured mitochondrial respiration, reactive oxygen species production, and oxidative damage in livers of house finches infected with or without Mg. To our surprise, MG did not changes both basal and maximal mitochondrial respiration capacities or mitochondrial reactive oxygen species production rate. However, Mg infected finches showed lower oxidative lipid and protein damage in liver when compared to uninfected counterparts. This result supported the immunosuppression hypothesis, where Mg decreased immune function of infected house finches. Low metabolic demand caused by immunosuppressive property of Mg could result in relatively low oxidative damage for infected house finches.

115-5 ZHANG, D*; GABALDON, J; ROCHO-LEVINE, J; VAN DER HOOP, J; MOORE, M; SHORTER, K; University of Michigan, Dolphin Quest, Oahu, Arhus University, Woods Hole Oceanographic Institution; *zhding@umich.edu*

Investigating bottlenose dolphin swimming biomechanics using biologging tags, tracking data, sensor fusion and estimation

Marine mammals must function effectively during extended periods without access to atmospheric oxygen during behaviors such as migration or foraging. How efficiently these animals swim directly affects oxygen management and determines both dive duration and activity levels that can be maintained. Therefore, an understanding of energetic cost during these behaviors is critical for determining the physiological (and thus behavioral) envelope of diving animals, and the consequences of anthropogenic stressors on their fitness. However, direct measurements of energetic cost or external forces (thrust for propulsion or drag on the body) are challenging for large swimming animals. Recent work has been conducted to directly measure the thrust created by swimming bottlenose dolphins using particle image velocimetry. But, these studies are limited by camera-based kinematic data collection in controlled environments that restrict data collection to a few fluke strokes of straight-line swimming, and are not practical for use with wild animals. As such, energetic expenditures of free-swimming whales and dolphins can be estimated only by using proxies such as heart rate, respiration rate or body acceleration. Further, experimental validation of these proxies has been limited. This work seeks to create the knowledge necessary to estimate mechanical work, a key contributor to the overall metabolic cost of free-swimming cetaceans. Here we present new estimation algorithms to combine data from multi-sensor tags and models of swimming kinematics to estimate per-stroke work and power during swimming. These estimates were evaluated in a controlled experimental environment with managed animals during controlled swimming tasks.

115-3 ZHU, JJ; WHITE, CH*; WAINWRIGHT, DK; DI SANTO, V; LAUDER, GV; BART-SMITH, H; Univ. of Virginia, Harvard Univ., Harvard Univ.; *chw8hq@virginia.edu*

Design and Performance of a High Speed Thunniform Swimming Platform

Bio-inspired "fish-like" robots come in a multitude of designs but are usually limited by slow speed, energy inefficiency, and high cost. Furthermore, few comprehensive comparative studies exist between such vehicles and their biological counterparts. We developed a thunniform robotic platform to study essential components of thunniform locomotion: kinematics, morphology, tail beat frequency, swimming speed, cost of transport, power consumption, Strouhal number, and thrust. The platform achieved a maximum tail beat frequency of 15 Hz which is comparable to tuna fish, and its maximum speed is 4.0 BL/s. High speed video captured the swimming mechanics of the platform from the ventral view at 1000 frames/s. Midline kinematics extracted from these videos were analyzed and compared against corresponding biological data, specifically the Atlantic mackerel fish (Scomber scombrus). We found that the effective angle of attack of the mackerel's caudal fin is within the optimal range for dynamic stall except during the transition between tail beat directions. Conversely, the Tunabot's rigid tail experiences effective angles of attack beyond deep dynamic stall for most of the tail beat period. This difference suggests the mackerel produces superior thrust by retaining the leading edge vortex, whereas the platform's caudal fin quickly releases its leading edge vortex.

115-2 ZHU, R*; WANG, J; DONG, H; BART-SMITH, H; Univ. of Virginia; *rz6eg@virginia.edu*

Computational Study of Tuna-Shaped Panel with Simultaneously Heaving and Bending Motion

We consider the propulsive performance of an unsteady heaving and bending foil with shape inspired by Thunniform swimmers such as tuna, computationally studying a parameter space of frequencies and phase offsets between heave and bend motions. The phase offset Φ between the heaving and bending motions proves to be critical in determining the propulsive performance and flow structure of the fish-shaped panel. To maximize thrust, the heave and bend motions have to be in-phase but not completely ($\Phi \sim 330°$), while to maximize efficiency, the bending motion needs to lag the heave motion by about quarter of period, which results in a motion of caudal fin at modest angle of attack.

1-2 ZIADI, P*; BLAKELY , B; CERBONE, B; ANDERSON, R; Florida Atlantic University, Florida Atlantic University ; *mziadi@fau.edu*

Testing hypotheses about song type matching and song sequences in songbird vocal repertoires

In order to extract meaning from a communication signal, it is important to understand both the context of the communication (e.g., intrasexual competition or courtship) as well as how an individual's vocal units are organized and delivered. In this project, we aim to understand how Bachman's sparrows structure the delivery of their large "primary" song type repertoires (>45 song types) and the potential role that song delivery patterns play in intraspecific vocal interactions. In a field study we presented male Bachman's sparrows with simulated territorial intrusions and each subject received two song playback treatments: 1) songs played in the sequence in which the subject bird sang them during a natural bout of undisturbed broadcast singing (ABCDE), and 2) songs played in a jumbled order (e.g., CEADB). We compared responses to the two playback treatments and found no differences in song type matching, song rate, song type switching frequency, or aggressive behaviors. While there was a low incidence of song type matching during both treatments, subjects tended to song type match to the playback more frequently when songs were presented in the birds' own sequence (the song sequence produced during undisturbed broadcast singing) compared to songs played in a jumbled sequence. In ongoing analyses, we are using Markov models to test for predictable song delivery patterns in individual Bachman's sparrows during undisturbed singing, in response to simulated territorial intrusion, and during natural counter-singing interactions between neighbors. We will also test whether neighbor dyads, which tend to share song types in common, also share song sequences in common. Ultimately, we seek to understand the role that vocal unit sequences may play in agonistic communication.

P1-192 ZIEMBA, JL*; LANCE, SL; CAPPS, KA; University of Georgia; *julie.ziemba25@uga.edu*

Investigating Potential Ranavirus Reservoirs

Ranavirus is a global pathogen of ectothermic vertebrates that can cause the mass-mortality of entire amphibian communities. However, asymptomatic amphibians have also tested positive for ranavirus in the field. In ephemeral wetland systems, it has been hypothesized that reservoir species retain sublethal infections from year-to-year between pond-filling events and subsequently reintroduce ranavirus to the community. Yet, our understanding of sublethal infection prevalence and the ways in which sublethally-infected individuals impact disease transmission is poor. Our objectives were to 1) explore disease susceptibility at low doses of ranavirus exposure and 2) examine the potential for chronic sublethal ranavirus infection. We conducted a series of laboratory dose-response experiments using *Pseudacris ornata*, *Lithobates capito,* and *Ambystoma talpoideum*. For each species, larvae were assigned to one of four doses ranging from 0 to 10^3 plaque-forming units of a local strain of ranavirus. Between one to two months after exposure, we sacrificed the survivors and dissected liver tissue for DNA extraction and qPCR. We found interspecific variability in susceptibility to low doses of ranavirus. Across doses, only *P. ornata* and *L. capito* larvae showed symptoms of ranavirus (hemorrhaging and acute death). Exposure to 10^2 plaque-forming units of ranavirus or fewer resulted in only 7% survival of *P. ornata*, but ~77% survival of *L. capito* and 100% survival of *A. talpoideum*. Ranavirus was not detected in the liver tissue of any surviving individuals, regardless of dose or species, suggesting resistance to infection, or the ability to clear the pathogen following infection. Although we found no evidence for chronic sublethal ranavirus infection, the growing documentation of apparently healthy, ranavirus-positive amphibians warrants further investigation of amphibian ranavirus reservoirs.

102-6 ZIMMER, C*; ROSVALL, KA; ARDIA, DR; TAYLOR, AR; BENTZ, AB; TAFF, CC; VITOUSEK, MN; Cornell University, Ithaca, Indiana University, Bloomington, Franklin and Marshall College, Lancaster, University of Alaska, Anchorage; *cgg.zimmer@gmail.com*

Differential MR and GR Expression in the Tree Swallow Brain is Associated with Individual Variation in Stress Physiology

Glucocorticoids (GCs) are central coordinators of metabolic processes and responses to challenges. Because of the diversity of adaptive traits they mediate, it is predicted that individual variation in the regulation of glucocorticoid signaling systems could influence the ability to survive or reproduce. Thus, many studies have investigated the relationship between circulating glucocorticoids and fitness proxies. However, because the downstream effects of GCs depend on the receptors to which they bind, understanding variation in receptor expression may be crucial for understanding hormone-fitness relationships. GCs bind to two primary receptors, the high affinity low capacity mineralocorticoid receptor (MR) and the low affinity high capacity glucocorticoid receptor (GR). We determined if patterns of MR and GR gene expression in the hippocampus, hypothalamus, and pituitary gland predict individual differences in baseline and stress-induced GC levels, and the efficacy of negative feedback in breeding female tree swallows (*Tachycineta bicolor*). MR gene expression in the hypothalamus was positively correlated with baseline and stress-induced GC levels. Birds with higher GR expression in the hypothalamus and higher MR expression in the pituitary gland were characterized by having both high stress-induced GC levels and strong negative feedback. This GC profile has been previously shown to confer greater stress resilience. These patterns therefore highlight important neuroendocrine mechanisms that may influence the degree to which challenges affect organismal phenotypes.

70-8 ZOGBAUM, L; NAVON, D; ALBERTSON, RC*; Bryn Mawr College, Univ. Massachusetts, Amherst; *albertson@bio.umass.edu*

Foraging Environment Influences Shape and Genetic Architecture of Cichlid Gill Raker Anatomy and Reveals New Roles for Hedgehog Signaling

The pharyngeal skeleton of bony fishes is an exquisitely evolved foraging structure, with nearly every bone along the buccal cavity modified to directly interface with prey items. The gill rakers (GRs) and pharyngeal jaws (PJs), in particular, are critical for filtering and processing food. These structures are highly diverse across teleost lineages and vary according to foraging niche. Moreover, plasticity of the pharyngeal skeleton in response to diet shifts has also been noted for several species. The relative contribution of genetics and the environment in shaping the pharyngeal skeleton remains poorly understood. Here we explore the gene-by-environmental effects on cichlid GRs and PJs by rearing both pure bred species and their F3 hybrids in different foraging environments. We find that anatomical differences between species are dependent on the environment, owing to one species exhibiting a greater degree of plasticity than the other. Further, the genetic architecture of these traits is largely distinct between foraging environments. We did, however, note several "hotspots", whereby multiple pharyngeal skeletal traits map to a common genomic region. One of these, for GR number, maps to the ptch1 locus, previously implicated in cichlid oral jaw shape and plasticity. Since Hedgehog (Hh) signaling has not previously been implicated in GR development, we explored functional roles for this pathway in the zebrafish model. We show that the Hh pathway is both necessary and sufficient to maintain plasticity in GR number. These data provide novel insights into the gene-by-environmental effects that shape key aspects of the cichlid feeding apparatus.

P2-230 ZIMMERMAN, MK*; WOODRING, AK; LANDBERG, T; Arcadia University; *mzimmerman_01@arcadia.edu*

Carry-over Effects of Larval Density and Hydroperiod on American Toad Morphology and Jumping Performance

Small slow-moving animals such as the American Toad often experience high mortality during dispersal and can be prevented from populating suitable habitats in urban areas due to roads and established predators. Our goal was to introduce marked toads to an urban park with a man-made pond and test to see if there were carryover effects of larval environment on adult translocation success. We manipulated tadpole density (10 or 29 tadpoles/tank) and hydroperiod (60, 75 or 90 days) in the lab to increase phenotypic variation and maximize introduction success. We predicted that toads raised in relatively low density would have larger body sizes. Relatively short hydroperiod was predicted to produce metamorphosis sooner, resulting in reduced body size and jumping performance, however it produced larger snout-vent (SVL) and tibiofibula (leg) lengths. As expected, lower density toads had higher mass relative to SVL (ANOVA, $p>.0001$). Leg length was significantly affected by hydroperiod (ANOVA, $p=.02$), density (ANOVA, $p<.0001$), and their interaction (ANOVA, $p=.14$). Jump distance was significantly affected by leg length (ANOVA, $p=.013$), hydroperiod (ANOVA, $p=.04$), density (ANOVA, $p<.0001$), but not in their interaction (ANOVA, $p=.20$). Age at metamorphosis decreased jumping distance (ANOVA, $p=.04$). Manipulating larval environments may increase the range of phenotypic variation that selection can act on during translocation. However this is a high risk and high effort strategy when coupled with experimental research because it results in low survival in degraded habitats. Despite initially low survival of translocated toads, we hope this strategy to understand the phenotype-environment relationship will eventually help conservation efforts in urbanized environments.

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